

3.2 SOILS

SYNOPSIS

This section describes current conditions and potential impacts related to four subresources:

- Soils types and disturbance/removal;
- Permafrost degradation and hazards;
- Erosion by water, wind, or thermal process; and
- Soil chemical quality, including effects from contaminated sites and fugitive dust.

Each alternative is examined by major project component: mine site; transportation infrastructure; and pipeline.

The No Action Alternative is representative of existing conditions. No project-related impacts to soil conditions would exist under this alternative.

Expected Effects:

Alternative 2: Donlin Gold's Proposed Action

Mine Site: Net overall effects associated with the mine site would range from minor to moderate. Direct impacts would range from low to high intensity, although the intensity for most effects would be reduced to medium through reclamation or additional mitigation. Examples of effects at different intensity levels include: minor thaw settlement (low); best management practices (BMPs) performing effectively at controlling erosion, or arsenic-bearing dust deposition resulting in measurable increases above baseline (medium); and complete soil removal, or permafrost deformation at toe of the waste rock facility (WRF) (high).

Soil removal would result in the permanent alteration of a total of roughly 9,000 acres of soil and discontinuous permafrost. The duration of fugitive dust effects would be permanent, potentially accumulating and persisting over the life of the mine and remaining at similar levels following mine closure; whereas the duration of erosion effects would range from temporary to long-term, with impacts potentially lasting for months or years until stabilization is achieved. The extent of soil disturbance, permafrost, and erosion effects would be local, as they would be limited to areas within the mine footprint and project property boundaries. Fugitive dust effects would range from local to regional, in that they could be measurable as far as 10 miles from the mine. The context of soil and permafrost effects would range from common, based on their regional distribution, to important, for those effects that are governed by regulation (e.g., erosion).

Transportation Facilities: Net overall effects associated with the transportation facilities would range from minor to moderate. As with the mine site, impacts would range from low to high intensity, although the intensity for most effects would be reduced to low to medium intensity through reclamation or other mitigation (e.g., off-road vehicle [ORV] access restrictions, or remediation preventing spread of existing soil contamination). Examples of effects at different intensity levels include: minor soil compaction, or arsenic in road dust at levels similar to baseline (low); thermal erosion at Jungjuk port stockpile, or contaminated soils at Dutch Harbor requiring removal (medium); and complete soil removal at road cuts, or ORV erosion in certain soil types (high).

Soil disturbances would result in permanent alteration of roughly 900 acres of surface soil and associated erosion and permafrost (where present), an extent considered mostly local as they would be limited geographically to areas within the footprints of the individual infrastructure components, although ORV use could extend beyond the immediate vicinity of the mine access road. The duration of erosion effects could range from temporary (e.g., several months) to permanent (e.g., ORV soil degradation). The extent of dust and contaminated sites effects would be local, as they would be limited to areas within the vicinity of individual facility footprints (e.g., dust on order of 1/10th mile from road). The context of soil and permafrost effects would range from common, based on their regional distribution, to important for those effects that are governed by regulation (e.g., erosion, contaminated sites).

Pipeline: Net overall effects associated with the pipeline would range from minor to moderate. Impacts would range from low to high intensity, although the intensity for most effects would be reduced to low to medium through effective design, reclamation, access limitations, or other mitigation. Examples of effects at different intensity levels include: minor compaction in winter construction areas (low); thaw settlement and thermal erosion effectively controlled through pipeline design and BMPs (medium); and complete soil removal at right-of-way (ROW) cuts, isolated ROW erosion incidents during construction, or heavy ORV use near Farewell (high).

Soil disturbances under Alternative 2 would impact a total of 8,350 to 14,100 acres, depending on the amount of additional ROW space needed in areas of challenging ground conditions. The extent of soil disturbance, erosion, and contaminated sites effects would be considered local, as they would be limited to areas within the footprint or immediate vicinity of the ROW and individual infrastructure components. Indirect ORV erosion effects could range from local (discrete segments of ROW) to regional (potentially extending for miles beyond the ROW if used to access new areas). The geographic extent of permafrost effects would be localized along intermittent ice-rich areas, mostly occurring along the north flank of the Alaska Range. Soils and permafrost would be permanently altered in areas of medium to high intensity effects, although the duration of most effects following reclamation would range from temporary to long-term until stabilization criteria are met. Effects from contaminated site (e.g., at Farewell airstrip) would be temporary, lasting through construction only. The context of soil

and permafrost effects would range from common, based on their regional distribution, to important, for those effects that are governed by regulation (e.g., erosion, contaminated sites).

Other Alternatives:

- *Alternative 3A (LNG-Powered Haul Trucks)* – Net overall effects would range from minor to moderate. There would be a small reduction in impacts to Kuskokwim River bank soils at relay points due to less low water travel, a reduction in soil and permafrost disturbance at ports by about 10 to 20 acres, and a slight reduction in fugitive dust from less fuel truck traffic on the mine access road.
- *Alternative 3B (Diesel Pipeline)* – Net overall effects would range from minor to moderate. Up to an additional 900 acres of soil would be disturbed due to the increased length of ROW and associated facilities. There would be no change in permafrost effects (no permafrost between Beluga and Tyonek), and erosion effects would occur and be managed at the same levels of intensity as those under Alternative 2. There could be an increase in contaminated soils encountered during construction in the Beluga-Tyonek area and at Puntilla airstrip.
- *Alternative 4 (Birch Tree Crossing [BTC] Port)* – Net overall effects for soils and permafrost would be moderate. For transportation facilities, the extent of permanently altered soils and permafrost (total removal, buried by fill, thaw settlement) would cover about 40 more miles of road and 39 more acres at the port than the proposed action. There would be greater potential for repeated fill repairs in localized thermokarst areas along the mine access road, and additional soil compaction and permafrost degradation effects beneath 12 miles of ice road. Direct erosion effects would be managed through BMPs similar to Alternative 2, although erosion at the Birch Tree Crossing (BTC) port site could be of lower intensity due to reuse of berth construction soils in material site reclamation, and there would be less disturbance of riverbank soils due to fewer relay points along the Kuskokwim River. Indirect effects from ORV use of the BTC road would potentially be higher under Alternative 4 due to a higher occurrence of organic-rich and permafrost soils, and closer proximity to population centers.
- *Alternative 5A (Dry Stack Tailings)* – Overall effects for soils and permafrost would be moderate. There would be a slightly greater area of soil disturbance (about 85 acres more for the Tailings Storage Facility (TSF) and filter plant) and permafrost removal beneath dams (due to larger combined footprints) than Alternative 2. There would likely be an increase in erosion effects due to increased surface area (up to 60 percent more) exposed to wind and water erosion, and to the complexity of erosion and sedimentation controls (ESCs) and BMPs at the dry stack. The increase in stockpile surface area (12 percent) is expected to be manageable with BMPs. The intensity and duration of dust deposition impacts would be similar to Alternative 2 (e.g., arsenic-bearing dust deposition resulting in small permanent increases in soil concentration exceeding naturally high baseline), although a slightly broader distribution of impacts

is possible due to a small increase in the amount of dust for the mine site as a whole (6.6 percent).

- *Alternative 6A (Dalzell Gorge Route)* – Net overall effects would range from minor to moderate. Up to an additional 1,300 acres of soil (about 9 percent more than Alternative 2) would be disturbed for the pipeline due to the greater area of off-ROW surface disturbance. Alternative 6A has a greater lateral extent of permafrost, particularly unstable permafrost, along the ROW (about 10 miles more), but less modeled vertical thaw settlement than Alternative 2, although differences in the amount of geotechnical data and thaw modeling conducted likely accounts for these apparent differences. Alternative 6A is roughly similar to Alternative 2 with respect to erosion susceptibility.

3.2.1 REGULATORY FRAMEWORK

Various laws and regulations pertain to the soils and soil conditions in the proposed Project Area. A preliminary review of public-record documents available from local, state, and federal agencies was conducted to evaluate baseline conditions related to soil quality and past handling and use of hazardous and non-hazardous materials and petroleum products, which resulted in contaminated properties within, adjacent to, and in relative proximity to proposed project components. The various databases and associated regulatory framework used to perform the preliminary review are described in the subsections below, in addition to regulatory requirements pertaining to soil by applicable agencies.

3.2.1.1 EPA

Databases maintained by the U.S. Environmental Protection Agency (EPA) list information regarding environmental cleanup activities for affected lands under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, and impaired waters designated under the Clean Water Act (CWA). Uncontrolled and abandoned hazardous waste sites that are perceived to be a major threat to both surrounding populations and the environment can be placed on the EPA National Priorities List, commonly referred to as the Superfund list; both non-Superfund and Superfund sites are regulated by CERCLA. The Comprehensive Environmental Response and Liability Information System (CERCLIS) is a database maintained by the EPA as part of the Superfund program, and includes potential and confirmed hazardous wastes sites at which the EPA Superfund program has some involvement. The Superfund database (EPA 2013I) provides available information through November 11, 2013.

The review also included CWA Impaired Water Section 303(d) listings for the proposed Project Area. Although these listings directly apply to water bodies, some can be associated with impaired soil conditions resulting in the release of toxic and other deleterious organic and inorganic substances.

3.2.1.2 ADEC

The Alaska Department of Environmental Conservation (ADEC) Contaminated Sites Program has database lists of known contaminated sites and leaking underground storage tanks (LUSTs) throughout Alaska. The database provides information regarding the type of contaminant released to the environment, the type(s) of media (air, water, soil, rock) affected by the contaminant, the Potential Responsible Party for cleaning up the documented release, and the location where the release occurred (ADEC 2013a). Lands within the Contaminated Sites Program are regulated under Title 18 of the Alaska Administrative Code (AAC) Chapters 75 and 78 (18 AAC 78) (ADEC 2012a, 2012b). ADEC oversees regulatory compliance work at contaminated sites, from discovery to site characterization and overall cleanup process (ADEC 2009). The ADEC database has four different rankings of site status: Open (characterization or remediation ongoing), Cleanup Complete (Closed), Open with Institutional Controls, and Cleanup Complete with Institutional Controls. Institutional Controls may include: maintenance of physical or engineering measures to limit an activity that might interfere with cleanup or that might result in exposure to a hazardous substance at the site; restrictive covenants, easements, deed restrictions, or other measures that limit site use or conditions over time, or provide notice of any residual contamination; and, zoning restrictions or land use planning by a local government with land use authority (ADEC 2012a).

Stormwater Pollution Prevention Plans (SWPPPs) are required to regulate soil erosion during construction and operations as part of the Alaska Pollutant Discharge Elimination System (APDES) permitting program regulated by ADEC. The APDES program manages discharge criteria to water for compliance with Section 402 of the CWA. Concerns include, but are not limited to, dredged soil, mining wastes, rock, sand, dirt, and runoff from construction activities. Permits establish allowable discharge limits and other conditions (monitoring and compliance) to ensure that water quality is protected. Multiple plans addressing various aspects of stormwater pollution discharge from disturbed surfaces (soil) and other project components would detail applicable erosion control measures, monitoring, reclamation, and mitigation measures (i.e., best management practices [BMPs]).

3.2.1.3 PHMSA

Permafrost-bearing soils can be susceptible to thermal degradation and ground movement via settlement. Soils most susceptible to these processes are considered thaw unstable soils. Segments of pipeline where the magnitude of differential settlement is anticipated to be greatest will likely occur between transitions to and from thaw unstable soil. For these reasons, strain-based pipeline design and associated permitting for differential ground movement may be required by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA). Strain-based pipeline serviceability and safety considerations include pipe diameter and wall thickness, material strength, and load stress-strain under longitudinal plastic deformation (strain greater than 0.5 percent). This pipeline will require safety conditions beyond the requirements of the present gas pipeline code (49 Code of Federal Regulations [CFR] Part 192). The conditions will include design, pipeline materials, construction, and operations and maintenance (O&M) practices to ensure that measures are in place to mitigate strains in areas where strains are anticipated to approach or be above 0.5 percent.

3.2.1.4 OTHER

In addition to ADEC, soil erosion is regulated by several other entities. The Alaska Department of Natural Resources (ADNR) also has applicable regulations regarding certain soil disturbances derived from project related activities. These include, but are not limited to various land use permit requirements and reclamation planning. ADNR approval of these permits and plans would be required prior to initiating project activities. Plan objectives would address mitigation measures, control features, and reclamation activities compatible with approved land uses.

The Alaska Department of Fish and Game (ADF&G) provides guidelines for stream bank erosion control. During closure and post-closure, stream banks would be reclaimed to conditions per ADFG guidelines and ADNR bonding and reclamation requirements.

Details regarding specific regulatory required plans applicable to soil throughout the project are presented in Section 3.2.3, Environmental Consequences.

3.2.2 AFFECTED ENVIRONMENT

This section presents a description of soils for the mine site (Section 3.2.2.1), transportation facilities (Section 3.2.2.2), and pipeline (Section 3.2.2.3) components of the proposed project. The following overview includes information available regarding the types of soil, presence or absence of permafrost, erosion characteristics, soil quality and contaminated sites with regard to each proposed component.

3.2.2.1 MINE SITE

3.2.2.1.1 SOIL TYPES

There are numerous soil studies and literature resources pertinent to the project study area. The available information is based on variety of soil classification criteria used to satisfy the practical needs of each study performed. For these reasons, variations in soil descriptions exist amongst the resources available. Soil descriptions derived from geotechnical studies are typically based on the Unified Soil Classification System (USCS) that categorizes mineral and organic soils based on particle-size characteristics and texture, properties that affect their use and physical behavior in construction. The U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) provides a variety of baseline soil data intended to assist in land resource planning and management, including classifications based on soil taxonomy, drainage, slopes, vegetative growth potential, and suitability for various land uses and development. Soil descriptions based on project geotechnical studies are provided in Section 3.1, Geology, in the discussion of proposed mine site surficial deposits. NRCS soils descriptions are presented below.

Based on available NRCS data applicable to the proposed mine site, two specific soil map units exist within the proposed mine site area (NRCS 2008). These are shown on Figure 3.2-1. Each map unit is made up of the major soils components for which it is named, plus one or more minor components that, because of the scale used, were not mapped separately. The map units at the proposed mine site and their corresponding major soil types are provided in Table 3.2-1. These consist mostly of silty gravelly soils associated with colluvium, loess, and weathered

bedrock on upland slopes; and loamy, gravelly and silty soils associated with the floodplains and stream terraces along Crooked Creek.

Site-specific field taxonomic classification data was collected for approximately half of the proposed mine site in support of a Preliminary Jurisdictional Wetlands Determination (3PPI et al. 2012). The study area data set is located north of the proposed pit, and captures the dominant soil types observed. A total of 23 soil types were identified in the proposed mine site area, of which three types accounted for approximately three-quarters of total soils documented. These three soil types and the corresponding percent of the mapped area covered by each, are:

- Hemic Glacistel – 41 percent: Glacistels are typically associated with Boreal Scrub and organic plains.
- Typic or Lithic Dystrocryept – 26 percent: Typic Dystrocryepts are associated with shoulder slopes, saddles, and footslopes or toeslopes. Lithic Dystrocryepts have a lithic or bedrock contact within 20 inches of the soil surface.
- Glacic Historthel – 7 percent: Historthels are typically associated with footslopes with open black spruce forest-shrub and spruce woodlands-shrub.

The results of the (3PPI et al. 2012) study are described in more detail in Section 3.11, Wetlands.

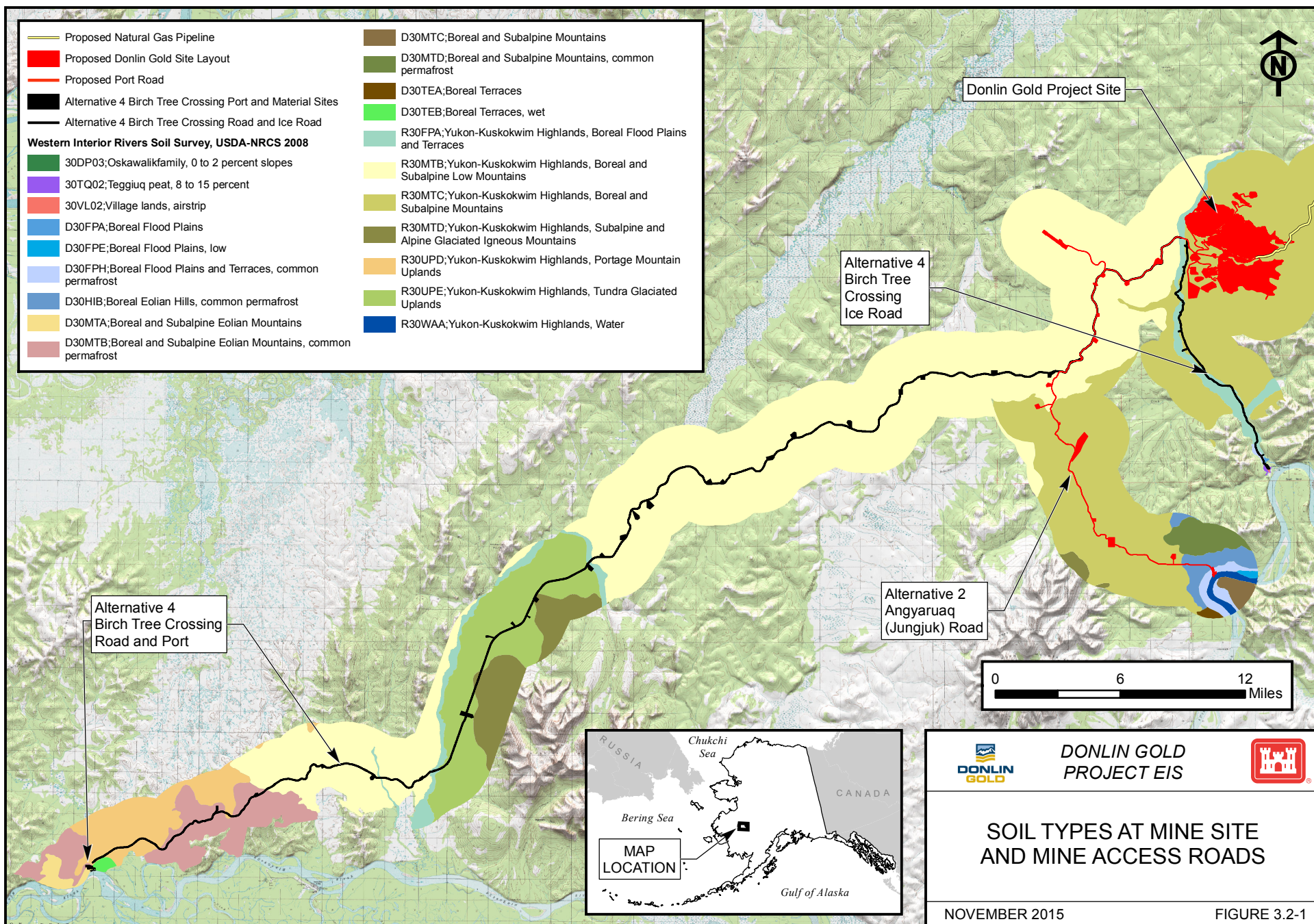


Table 3.2-1: Mine Site Soil Types and Erosion Hazards

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
R30FPA: Yukon-Kuskokwim Highlands, Boreal Floodplains and Terraces							
Boreal forest, gravelly floodplains and similar soils	Fluventic Haplocrypts	Loamy alluvium over sandy and gravelly alluvium	Toeslopes of floodplains on mountains	0 to 2	Moderately well drained; occasional flooding	Slight	Moderate
Boreal forest, loamy floodplains and similar soils	Aquic Cryofluvents	Coarse-loamy alluvium	Floodplains	0 to 5	Moderately well drained; occasional flooding	Slight	Moderate
Boreal scrub, gravelly floodplains and similar soils	Aquic Cryorthents	Sandy and gravelly alluvium	Floodplains	0 to 7	Somewhat poorly drained; occasional flooding	Slight	Moderate
Boreal scrub, silty terraces and similar soils	Typic Cryaquepts	Organic mat over silty alluvium and/or loess over gravelly alluvium	Terraces	0 to 5	Very poorly drained; no flooding	Slight	Slight
R30MTC: Yukon-Kuskokwim Highlands, Boreal and Subalpine Mountains							
Boreal forest, gravelly colluvial slopes and similar soils	Typic Haplocryods	Loamy colluvium and/or loess over gravelly colluvium	Backslopes of mountains, hills	12 to 110	Well drained; no flooding	Severe	Slight
Boreal scrub, silty colluvial slopes and similar soils	Histic Cryaquepts	Organic mat over loamy alluvium over sandy and silty alluvium	Backslopes, footslopes of mountains	0 to 1	Very poorly drained; no flooding	Slight	Slight
Subalpine woodland, gravelly colluvial slopes and similar soils	Typic Dystrocrypts	Gravelly colluvium	Summits, backslopes, shoulders of hills, mountains	5 to 46	Wells drained; no flooding	Moderate	Moderate
Boreal taiga, loamy colluvial slopes and similar soils	Typic Histoturbels	Organic mat over loamy cryoturbate over permanently frozen loamy slope alluvium	Footslopes, backslopes of mountains, hills	2 to 29	Poorly drained; no flooding	Severe	Slight

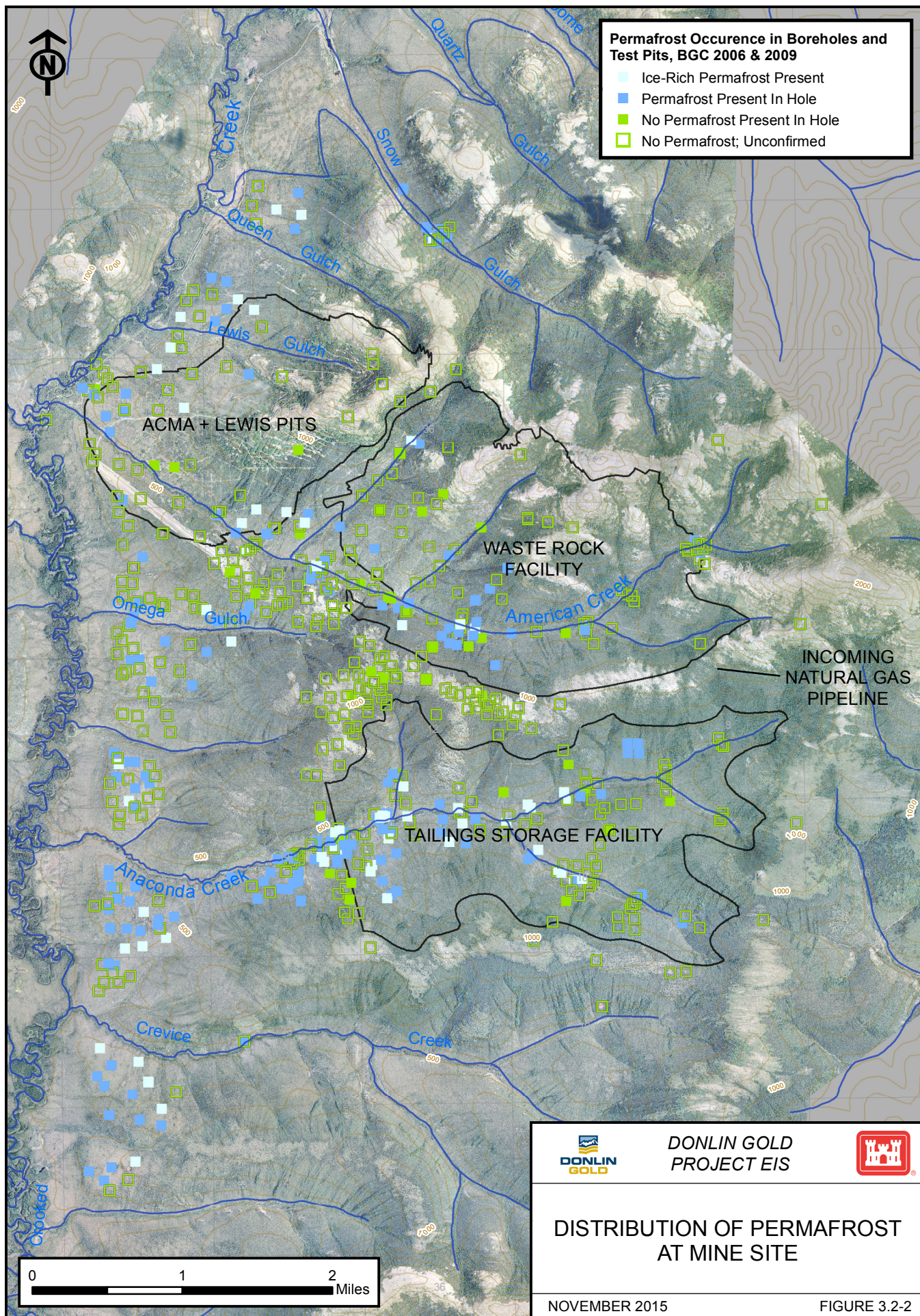
Notes:
Soil Map Units shown on Figure 3.2-1
Source: NRCS 2008.

3.2.2.1.2 PERMAFROST

Permafrost is soil or rock that is at or below the freezing temperature of water for two or more years. Regionally, the proposed mine site is located in an area characterized by discontinuous, moderately thick to thin permafrost in fine-grained soils, and isolated masses in coarse-grained soils (Ferrians 1965, 1994).

The approximate distribution of permafrost in the proposed mine site area was compiled by Donlin Gold, LLC based on recorded field observations in test pits and boreholes (BGC 2006, 2009a, 2011d) (Figure 3.2-2). Slope angle and aspect strongly influence solar radiation exposure, and therefore, permafrost distribution. For this reason, permafrost is more prevalent on north and east facing slopes. Permafrost also tends to be more prevalent in lower topographic features such as valley bottoms, drainages and toeslopes. In the proposed mine site area, vegetation tends to decrease with increasing elevation, reducing surface insulation. Consequently, these higher elevations tend to have thinner permafrost. Ice-rich permafrost is generally limited to overburden soils, and is often associated with the presence of peat and its insulating properties. High-ice-content soils and soils exhibiting ice segregation are generally associated with silt-bearing materials, although visible ice crystals can also exist in frozen gravelly materials (BGC 2006). Thin, discontinuous ice lenses, where present and measured in surficial deposits, range from 0.4 to 2 inches thick (BGC 2009a).

An average seasonal frost depth of 6.6 feet exists in the proposed mine site, but can vary from approximately 1.5 feet to 14 feet. Where present, a mean permafrost depth of approximately 19 feet was determined for the area, with reported depths ranging from approximately 7.5 feet to 105 feet near Anaconda Creek (BGC 2006). Although permafrost is generally limited to overburden soils, it occasionally extends into bedrock. Investigation at roughly one-quarter of the subsurface exploration sites encountered conditions where permafrost extended to the soil-bedrock interface. At approximately two-thirds of these locations, permafrost was limited to overburden materials, and in the remaining one-third, extended to depths of 6.6 to 10 feet into the weathered bedrock.



3.2.2.1.3 EROSION

Discontinuous permafrost, windy conditions, and unconsolidated overburden materials at the proposed mine site create the potential for thermal, wind, and hydraulic erosion.

Thermal erosion of ice-rich permafrost soils can lead to ground subsidence, slope instability and drainage alteration. Removal or disturbance of any overlying organic mat and vegetative materials can accelerate permafrost degradation rates. Developed thermokarst topography associated with permafrost instability is present along Crooked Creek and the lower benches of the proposed Project Area, and along the Crooked Creek floodplain from Donlin Creek to below Crevice Creek. Thermokarst is also present along interfluvial areas between gulches or drainages on lower benches (BGC 2005).

Wind erosion is the process of wind blowing away soil, silt, fine sand, or vegetation that is light enough to become airborne and deposited at a different location. The rate of soil displacement depends on weather conditions (wind velocity, precipitation, and temperature) as well as soil type and slope. Deforestation, excavation, and road construction increase the rate of wind erosion. These actions also impact drainage patterns and soil compaction, leading to exposure of mineral soil and a potential increase in hydraulic erosion. Wind erosion reduces the capacity of the soil to store nutrients and water, thus making the environment drier and affecting the porosity and permeability of the soils.

Two measures of soil susceptibility to wind erosion are used to describe soils present throughout the Project Area based on review of available NRCS information. One measure includes NRCS “hazard of erosion” descriptions ranging from none (i.e., na), slight, moderate, and severe as shown in Table 3.2-1. Another measure includes published wind erodibility group (WEG) values listed in applicable tables where no hazard of erosion description is available. The WEG is assigned to groupings of soils that have similar properties affecting their resistance to soil blowing in cultivated areas, which is similar to wind erosion susceptibility and dust potential following surface alteration. The WEG is based on properties of the soil surface layer and ranges from 1 through 8. Lower numbers are generally associated with greater susceptibility to erosion. For example, non-cohesive homogeneous sands susceptible to wind erosion could have a WEG value of 1, whereas bedrock, frozen soils, or saturated soils (e.g., muskegs) could have a WEG value of 8.

Hydraulic erosion is the removal and transport of soils by rainfall and flowing water. Specific conditions affecting hydraulic erosion vulnerability include inherent soil properties (cohesion), slope and flow velocities, and vegetative cover. Silt and sand soil types are generally more susceptible to various types of erosion than gravels and coarser material. Slope length and grade substantially influence soil erosion rates (Warren et al. 1989). Removal of protective surface organics also accelerates erosion processes in underlying non-cohesive soils.

Three NRCS measures are used to describe soil susceptibility to hydraulic erosion via runoff for different soil types. These include erosion hazard descriptions (e.g., na, slight, moderate, and severe), K-factor value, and T-factor value. Hazard of erosion descriptions are preferentially used in applicable tables for soil components where available (e.g., Table 3.2-1). In the absence of hazard of erosion descriptions, K- and T-factor values are provided in applicable tables. K-factor is a relative index of soil susceptibility to particle detachment (erosion) and transport due

to runoff. T-factor is a soil loss tolerance index used to describe soil sensitivity (productivity) to erosional losses.

Erosion factor K_w (K) indicates the erodibility of the whole soil. K-factors are grouped into 14 class values ranging from 0.02 to 0.69, where greater values are representative of increased erodibility. Values of K greater than 0.4 generally tend to produce higher rates of runoff and erosion (IWR 2002). With the exception of organic soils, NRCS assigns a K_w value for each soil horizon present at depth within the soil component, often resulting in multiple K_w values. The $K_{w(max)}$ value referenced in applicable tables represents the highest K_w value in soils extending to 18 inches below ground surface. This approach allows for a comparison of the erodibility of shallow surface soils most likely to be impacted by project-related disturbances, and is considered conservative since the greatest K_w value may not be representative of dominant soil horizons in the 18-inch interval evaluated.

Alternatively, the soil loss tolerance factor (T-factor) is used to describe soil sensitivity to erosional losses. The T-factor is defined as the maximum amount of annual erosion in tons per acre at which the quality of the soil can be maintained for plant growth; these values are commonly used as objectives for conservation planning purposes. T-factors range from 1 to 5 tons per acre soil loss (annual); are assigned to soils without respect to land use or cover; and represent a goal for maximum sustainable soil loss. Greater T-factor values correspond with soils that can tolerate more soil loss and maintain vegetation productivity. Higher values generally indicate deeper, more erosion-resistant soils; and lower values indicate thinner, more erosion-susceptible soils.

Erosion descriptions listed in Table 3.2-1 for soil map units in the proposed mine site area range from slight to severe for water-caused erosion, assuming that the organic mat has been removed (NRCS 2008). The hazard of erosion for the least prevalent soil map unit, located along Crooked Creek (R30FPA), is slight. The most prevalent soil map unit in the upland part of the proposed mine site (R30MTC) ranges from moderate to severe, with gravelly colluvial slopes exhibiting the highest susceptibility to water erosion. Wind erosion susceptibility, a measure of potential for airborne dust if soil is disturbed, ranges from slight to moderate for mine site soil types.

3.2.2.1.4 SOIL QUALITY/CONTAMINATED SITES

Review of the CWA Impaired Water Section 303(d) listings indicated that no such waterbody listings are present within the mine site project boundaries. Review of the CERCLIS database indicated that no known federally funded Superfund sites are present within the proposed mine site project boundaries. Review of the ADEC Contaminated Sites database indicates no identified contaminated sites in the proposed mine site area.

Elevated background concentrations of certain compounds in soils at the mine site could result in adverse concentrations in vegetation or soluble compounds in water that could potentially be derived from stripped overburden and fugitive dust associated with mine site activities. A summary of baseline concentrations and summary statistics of inorganic compounds in soils in the vicinity of the mine site are listed in Table 3.2-2. The distribution of baseline sample locations is shown in Figure 3.2-3.

While not currently applicable to the mine site, ADEC soil cleanup levels, which are administered through the State's Contaminated Sites Program, are listed in Table 3.2-2 for comparison purposes to provide a framework for understanding existing conditions. One element, arsenic, is naturally elevated in baseline soils compared to ADEC levels. The arithmetic mean is notably higher for this constituent than the geomean, indicating that the distribution of data is skewed and the arithmetic mean is sensitive to concentrations at the higher end of the distribution. In other words, there are a small number of high concentrations compared to the bulk of concentrations centered around the geomean value, which cause the arithmetic mean to be higher. High arsenic levels in soils from natural mineralized and volcanic sources are common in Alaska (e.g., Gough et al. 1988), and are present near the mine site as it is a component of the ore deposit (Section 3.7, Water Quality). Constituents exceeding the ADEC levels in both baseline soils and predicted fugitive dust are further evaluated in Section 3.2.3.2.4.

Table 3.2-2: Concentrations of Inorganics in Baseline Soils, Mine Site and Vicinity

Analyte ¹	Mean ² (ppm)	Standard Deviation ² (ppm)	95% UCL ² (ppm)	Geometric Mean ³ (ppm)	ADEC Soil Cleanup Level ⁴ (ppm)
Antimony	5.35	11.1	11.1	2.08	41
Arsenic	78.8	177	169	23.9	4.5
Barium	480	294	640	380	20,300
Beryllium	0.963	0.504	1.07	0.66	200
Cadmium	0.245	0.195	0.289	0.23	79
Cobalt	13.5	4.7	14.5	12.7	-
Chromium	58.1	27.8	63.9	52.7	300
Copper	33.9	36.9	54.1	26.3	4,100
Lead	12.9	6.1	14.0	12.0	400
Manganese	525	195	567	491	-
Mercury	0.212	0.342	0.415	0.123	30/18
Nickel	33.9	18.4	37.7	31.1	2,000
Selenium	2.07	0.72	2.27	1.94	510
Silver	0.369	1.05	0.909	0.17	510
Thallium	0.535	0.203	0.592	1.36	8.1
Uranium	2.41	0.61	2.59	3.23	-
Vanadium	80.7	36.4	88.3	72.5	710
Zinc	91.7	27.7	97.4	88.7	30,400

Notes:

1 Baseline data sources: For all metals except mercury, data from Fernandez 2014a: (Donlin Soil Samples 20140825.xlsx); n = 64 to 73. For mercury, data from ARCADIS (2007c, 2014); n = 54. Rubble/outcrop data not included.

2 For arithmetic mean, standard deviation, and 95% UCL, datasets with nondetects estimated by the Kaplan-Meier (KM) method.

3 Geomean estimated using 1/2 the detection limit for nondetects.

4 18 AAC 75: Method Two, Under 40-inch Zone; direct contact route for all metals; direct contact/outdoor inhalation for mercury.

Shaded cells = Baseline concentrations exceed ADEC soil cleanup levels.

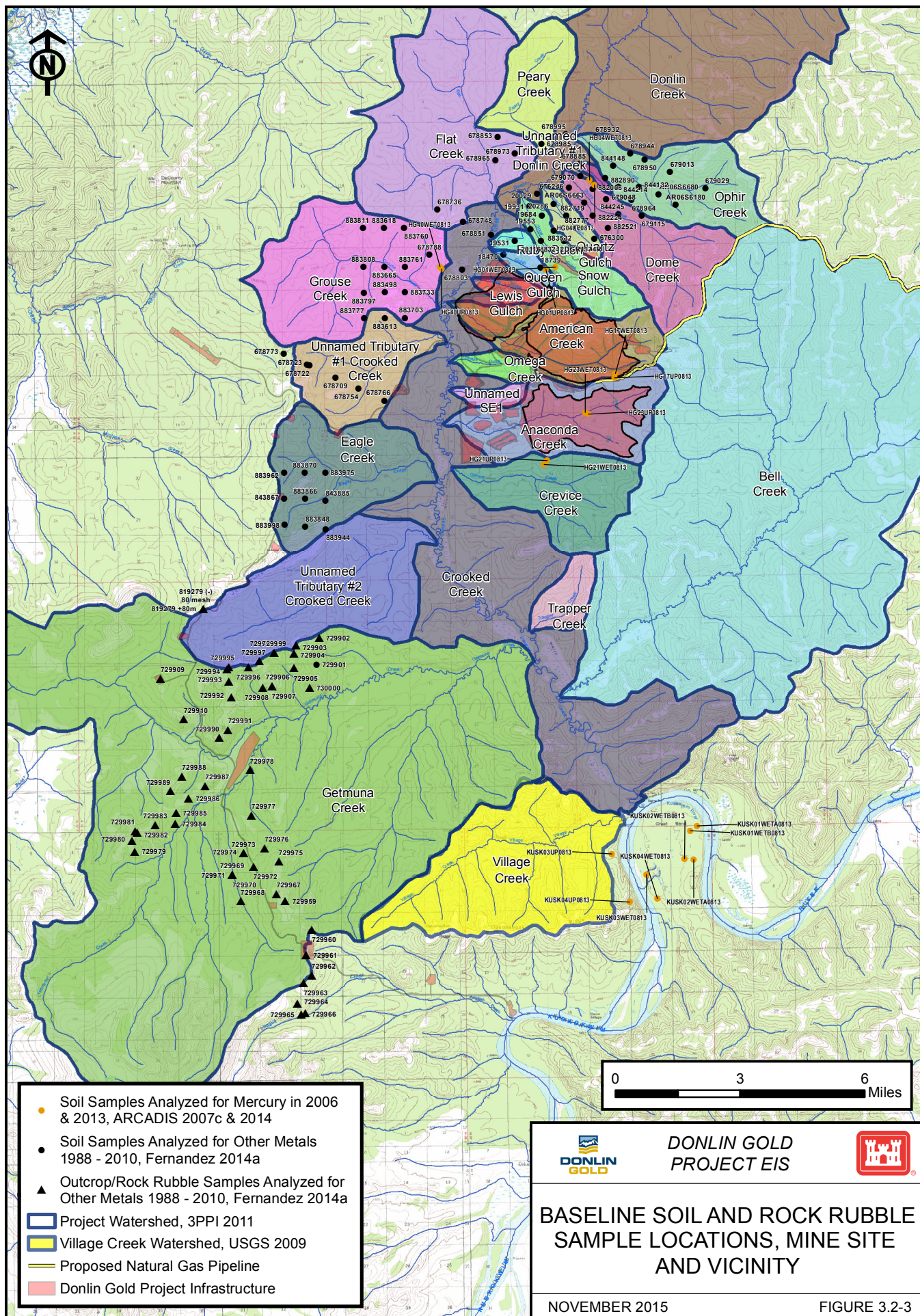
Abbreviations:

- Not available

n number of samples

95% UCL 95 percent upper confidence limit on the mean

ADEC Alaska Department of Environmental Conservation



Hydrocarbons and cyanide may be present in natural soils and vegetation at the mine site. No baseline data have been collected for these constituents in soils, and there have been no reported or suspected adverse soil conditions from hydrocarbons or cyanide from past and current project developments (Weglinski 2015f).

3.2.2.2 TRANSPORTATION FACILITIES

3.2.2.2.1 SOIL TYPES

Surficial deposits and geotechnical investigations conducted by Donlin Gold along the proposed Angyaruaq (Jungjuk) and Birch Tree Crossing (BTC) Port alternatives are described in Section 3.1, Geology. NRCS soil types for these areas and other transportation components are summarized below.

Angyaruaq (Jungjuk) and Birch Tree Crossing Roads and Port Sites

Based on available NRCS data, a total of five soil map units coincide with the proposed Angyaruaq (Jungjuk) Road and six with the BTC Road (NRCS 2008). The distribution of these units is shown on Figure 3.2-1, and their corresponding soil types are provided in Table 3.2-3. The identified units are representative of reconnaissance and detailed reconnaissance level mapping (3PPI et al. 2012).

The first 20 miles of proposed road corridor leading from the proposed mine site, where the Angyaruaq (Jungjuk) and BTC roads follow the same route, pass through soil unit R30MTB, which consists of loamy and gravelly soils associated with colluvium, loess, and weathered bedrock on upland slopes. The south half of the proposed Angyaruaq (Jungjuk) Road is dominated by the same silty gravelly colluvial soil unit (R30MTC) present at the proposed mine site. Soil types at the proposed Angyaruaq (Jungjuk) Port site include silty and loamy soils associated with eolian slopes (loess) and floodplains adjacent to the Kuskokwim River. The western half of the potential BTC route is dominated by glaciated upland soils (R30UPE) along the northwest flank of the Russian Mountains; coarse-loamy eolian deposits (D30MTB) in boreal and subalpine mountains; and silty to coarse-loamy cryoturbate soils (R30UPD) in uplands at the potential BTC road terminus.

Table 3.2-3: Soil Types and Erosion Hazards for Mine Road Alternatives

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Soil Descriptions Common to Angyaruaq (Jungjuk) and BTC Roads, and Crooked Creek Winter Road							
R30FPA: Yukon-Kuskokwim Highlands, Boreal Floodplains and Terraces							
Boreal forest, gravelly floodplains and similar soils	Fluventic Haplocrypts	Loamy alluvium over sandy and gravelly alluvium	Toeslopes of floodplains on mountains	0 to 2	Moderately well drained; occasional flooding	Slight	Moderate
Boreal forest, loamy floodplains and similar soils	Aquic Cryofluvents	Coarse-loamy alluvium	Floodplains	0 to 5	Moderately well drained; occasional flooding	Slight	Moderate
Boreal scrub, gravelly floodplains and similar soils	Aquic Cryorthents	Sandy and gravelly alluvium	Floodplains	0 to 7	Somewhat poorly drained, occasional flooding	Slight	Moderate
Boreal scrub, silty terraces and similar soils	Typic Cryaquepts	Organic mat over silty alluvium and/or loess over gravelly alluvium	Terraces	0 to 5	Very poorly drained, no flooding	Slight	Slight
R30MTB: Yukon-Kuskokwim Highlands, Boreal and Subalpine Low Mountains							
Boreal taiga, loamy colluvial slopes and similar soils	Typic Histoturbels	Organic mat over loamy cryoturbate over permanently frozen loamy slope alluvium	Footslopes, backslopes of mountains, hills	2 to 29	Poorly drained; no flooding	Severe	Slight
Boreal forest, gravelly colluvial slopes and similar soils	Typic Haplocryods	Loamy colluvium and/or loess over gravelly colluvium	Backslopes of mountains, hills	15 to 25	Well drained; no flooding	Severe	Slight
Boreal scrub, loamy eolian slopes and similar soils	Typic Haplocryods	Coarse-loamy eolian deposits	Shoulders, backslopes of terraces, hills	1 to 40	Well drained; no flooding	Severe	Severe
Subalpine forest, gravelly residual slopes and similar soils	Spodic Dystrocrypts	Gravelly residuum	Backslopes, shoulders of hills, mountains	4 to 50	Well drained; no flooding	Severe	Moderate
Subalpine scrub, loamy colluvial slopes and similar soils	Typic Dystrocrypts	Loamy colluvium over gravelly colluvium	Backslopes of swales on hills, drainage ways on hills	2 to 45	Moderately well drained; no flooding	Severe	Moderate

Table 3.2-3: Soil Types and Erosion Hazards for Mine Road Alternatives

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Soil Descriptions Specific to Angyaruaq (Jungjuk) Road							
R30MTC: Yukon-Kuskokwim Highlands, Boreal and Subalpine Mountains							
Boreal forest, gravelly colluvial slopes and similar soils	Typic Haplocryods	Loamy colluvium and/or loess over gravelly colluvium	Backslopes of mountains, hills	12 to 110	Well drained; no flooding	Severe	Slight
Boreal scrub, silty colluvial slopes and similar soils	Histic Cryaquepts	Organic mat over loamy alluvium over sandy and silty alluvium	Backslopes, footslopes of mountains	0 to 1	Very poorly drained; no flooding	Slight	Slight
Subalpine woodland, gravelly colluvial slopes and similar soils	Typic Dystrocryepts	Gravelly colluvium	Summits, backslopes, shoulders of hills, mountains	5 to 46	Wells drained; no flooding	Moderate	Moderate
Boreal taiga, loamy colluvial slopes and similar soils	Typic Histoturbels	Organic mat over loamy cryoturbate over permanently frozen loamy slope alluvium	Footslopes, backslopes of mountains, hills	2 to 29	Poorly drained; no flooding	Severe	Slight
D30HIB: Boreal Eolian Hills; common permafrost							
Boreal forest, silty eolian slopes and similar soils	Typic Dystrocryepts	Loess	Toeslopes, backslopes, shoulders of hills, alluvial fans, terraces	4 to 38	Well drained; no flooding	Severe	Severe
Boreal taiga, loamy eolian slopes and similar soils	Typic Histoturbels	Organic mat over coarse-loamy cryoturbate over permanently frozen coarse-loamy eolian deposits	Footslopes, toeslopes of terraces, hills	1 to 23	Poorly drained; no flooding	Moderate	Slight
Boreal scrub-sedge, loamy eolian slopes and similar soils	Typic Haplocryods	Organic mat over coarse-loamy eolian deposits	Footslopes, toeslopes of hills	2 to 12	Poorly drained; no flooding	Moderate	Slight
D30FPH: Boreal Floodplains and Terraces, common permafrost							
Boreal scrub, loamy floodplains and similar soils	Typic Aquorthels	Loamy alluvium over permanently frozen sandy and silty alluvium	Floodplains	0 to 2	Poorly drained; occasional flooding	Slight	Slight
Boreal scrub, silty floodplains and similar soils	Fluvaquentic Cryaquepts	Coarse-silty alluvium	Footslopes, backslopes of hills, floodplains	0 to 8	Poorly drained; occasional flooding	Slight	Severe

Table 3.2-3: Soil Types and Erosion Hazards for Mine Road Alternatives

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Boreal forest, loamy floodplains and similar soils	Aquic Cryofluvents	Coarse-loamy alluvium	Floodplains	0 to 5	Moderately well drained; occasional flooding	Slight	Moderate
Soil Descriptions Specific to BTC Road							
D30MTB: Boreal and Subalpine Eolian Mountains, common permafrost							
Boreal woodland, loamy eolian slopes and similar soils	Aquic Dystrocrypts	Coarse-loamy eolian deposits	Backslopes, shoulders, toeslopes, summits of hills, terraces	3 to 40	Well drained; no flooding	Moderate	Severe
Boreal taiga, loamy eolian slopes and similar soils	Typic Histoturbels	Organic material over coarse-loamy cryoturbate over permanently frozen coarse-loamy eolian deposits	Toeslopes, footslopes of hills, terraces	1 to 23	Poorly drained; no flooding	Moderate	Slight
Boreal forest, loamy eolian slopes and similar soils	Typic Haplocryods	Coarse-loamy eolian deposits over gravelly colluvium	Backslopes, shoulders, summits of mountains, hills	4 to 20	Well drained; no flooding	Severe	Moderate
R30MTD: Yukon Kuskokwim Highlands, Subalpine and Alpine Glaciated Igneous Mountains							
Alpine herbaceous, gravelly colluvial slopes and similar soils	Typic Dystrogelepts	Loess and/or silty colluvium over gravelly colluvium	Summits, shoulders, backslopes of mountains, hills	5 to 27	Well drained; no flooding	Severe	Moderate
Subalpine woodland, gravelly colluvial slopes and similar soils	Typic Dystrocrypts	Gravelly colluvium	Summits, backslopes of hills	5 to 46	Well drained; no flooding	Moderate	Moderate
Alpine dwarf scrub, gravelly till slopes and similar soils	Typic Humigelods	Gravelly till	Summits, shoulders of mountains	2 to 12	Well drained; no flooding	Slight	Moderate
R30UPD: Yukon-Kuskokwim Highlands, Portage Mountains Uplands							
Boreal tussock-scrub, loamy plains and similar soils	Typic Histoturbels	Organic mat over silty cryoturbate over permanently frozen loess	Toeslopes of hills and plains	2 to 8	Poorly drained; no flooding	Slight	Slight
Boreal dwarf scrub, silty plains and similar soils	Typic Aquiturbels	Silty cryoturbate over permanently frozen loess	Terraces and plains	2 to 5	Poorly drained; no flooding	Slight	Slight

Table 3.2-3: Soil Types and Erosion Hazards for Mine Road Alternatives

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Boreal sedge, organic depressions and similar soils	Histosols	Organic mat and/or grassy organic mat over loamy alluvium	Toeslopes of depressions on mountainsides	1 to 5	Very poorly drained; no flooding	Slight	Slight
Boreal scrub, loamy terraces and similar soils	Typic Histoturbels	Organic material over coarse-loamy cryoturbate and/or permanently frozen coarse-loamy eolian deposits	Terraces	0 to 8	Poorly drained; no flooding	Slight	Slight
R30UPE: Yukon-Kuskokwim Highlands, Tundra Glaciated Uplands							
Boreal tussock-scrub, loamy plains and similar soils	Typic Histoturbels	Organic material over silty cryoturbate over permanently frozen loess	Footslopes, toeslopes, backslopes of plains, hills	2 to 8	Poorly drained; no flooding	Slight	Slight
Boreal taiga, loamy eolian slopes and similar soils	Typic Histoturbels	Organic material over coarse-loamy cryoturbate over permanently frozen coarse-loamy eolian deposits	Toeslopes, footslopes of terraces, hills	1 to 23	Poorly drained; no flooding	Severe	Slight
Soil Types Specific to Crooked Creek Winter Road							
D30FPH: Boreal Floodplains and Terraces, common permafrost (see descriptions specific to Jungjuk [Angyaruq])							
R30MTC: Yukon-Kuskokwim Highlands, Boreal and Subalpine Mountains (see descriptions specific to Jungjuk [Angyaruq])							
30TQ02: Teggiuq peat, 8 to 15 percent							
Teggiuq and similar soils	Coarse-loamy, mixed, superactive, nonacid Typic Cryofluvents	Mossy organic materials over coarse-silty cryoturbate over permanently frozen coarse-silty eolian deposits	Footslopes, backslopes	8 to 15	Poorly drained; no flooding	Severe	Slight
D30FPA: Boreal Floodplains							
Boreal forest, loamy floodplains and similar soils	Aquic Cryofluvents	Coarse loamy alluvium	Floodplains	0 to 5	Moderately well drained; occasional flooding	Slight	Moderate

Table 3.2-3: Soil Types and Erosion Hazards for Mine Road Alternatives

Soil Map Unit and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
30DP03: Oskawalik Family							
Oskawalik family and similar soils	Coarse-silty, mixed, superactive, nonacid Fluvaquentic Cryaquepts	Loamy slope alluvium and/or gravelly slope alluvium	Alluvial fans	0 to 2	Poorly drained; occasional flooding	Slight	Slight

Notes:

BTC = Birch Tree Crossing

Soils map units shown on Figure 3.2-1.

Source: NRCS 2008.

Crooked Creek Winter Road

A single-season winter ice road, under Alternative 4, would be developed from the proposed mine site to the vicinity of Crooked Creek Village. The temporary ice road would support simultaneous construction of the proposed BTC road from opposing ends. A total of six soil types are present along the proposed winter road alignment, of which one is common to the Angyaruaq (Jungjuk) and BTC road alternatives, and two are shared with the Angyaruaq (Jungjuk) Road alternative (Figure 3.2-1). The three soil types exclusive to the temporary ice road alignment are limited to loamy alluvium deposits (D30FPA and 30DP03) and organic materials over silty eolian deposits (30TQ02). These soil types are found on relatively low angle slopes, and represent only a slight percentage of the total soils encountered along the alignment. These three soil types are limited to within 1 mile of the ice road terminus near the Village of Crooked Creek.

Bethel Port Site and Floodplain

Bethel area soil is typically composed of alluvial floodplain deposits of the Kuskokwim River consisting of silt, sand, and gravel interlayered with organic peat and wood (Dorava and Hogan 1995). The uplands bordering the Kuskokwim floodplain are generally underlain by fluvial sand and silt deposits (Hinton and Girdner 1967, 1975). The soil map unit associated with the Bethel area and Kuskokwim River floodplain, which also applies to both upstream port site alternatives, is Histic Pergelic Cryaquepts-Typic Cryofluvents, loamy nearly level association (USDA-SCS 1979). This unit and its principal components (Table 3.2-4) include both poorly drained soils with permafrost on lower portions of the floodplain, and well drained soils on natural levees along existing and former river channels with deeper permafrost.

Dutch Harbor

Surface materials in the Dutch Harbor area generally consist of glacial sediment and till, often overlain with soil containing ash and lapilli layers of volcanic tephra (Lemke and Vanderpool 1995). The soil horizon is often shallow, and can vary from 1.5 feet to 5 feet thick. The soil map unit (IA2) detailed in Table 3.2-4 is representative of soils present in lowlands and coastal

margins where existing Dutch Harbor port facilities are situated (USDA-SCS 1979). Volcanic bedrock at the Delta Western fuel farm on Amaknak Island lies at depths as shallow as 1 to 6.5 feet (ADEC 2013b).

Table 3.2-4: Soil Types at Bethel and Kuskokwim River Floodplain and Dutch Harbor

Soil Map Unit and Principal Components and Associations	Parent Material Description	Landscape Position	Drainage	Erosion Parameters	
				K _w (max)/T Factor	WEG
Bethel and Kuskokwim Floodplain Soil Descriptions					
IQ3 – Histic Pergelic Cryaquepts-Typic Cryofluvents, loamy, nearly level association					
IQ3-Histic Pergelic Cryaquepts, loamy, nearly level	Organic material over silt loam to sandy loam.	Floodplains	Poorly drained	--	--
IQ3-Typic Cryofluvents, loamy, nearly level	Stratified silt loam and fine sand	Floodplains	Well drained	--	--
IQ3-Pergelic Cryofibrists, nearly level	Organic material over permafrost	Floodplains	Poorly drained	--	--
IQ3-Typic Cryothents, very gravelly, nearly level	Stratified sand and silt over gravelly sand	Floodplains	Well drained	--	--
Dutch Harbor/Unalaska Soil Description					
IA2 – Typic Cryandepts, loamy, hilly, to steep-Rough mountainous land association					
IA2-Typic Cryandepts, loamy, hilly to steep	Organics over loamy, sandy, and cindery ash	Hills, footslopes	Well drained	--	--
IA2-Typic Cryandepts, loamy, Rough mountainous land	Volcanic cinders and hardened lava.	Mountains, volcano flanks	--	--	--
IA2-Typic Cryandepts, very gravelly, hilly to steep	Sandy volcanic ash	Mountains and hillslopes	--	--	--
IA2-Dystric Cryandepts, loamy, hilly to steep	Thixotropic volcanic ash and sandy or cindery ash	Hills, toeslopes	--	--	--
IA2-Fluvaquentic Cryofibrists	Organic fibrous sedge peat	Valley bottom depressions	Poorly drained	--	--

Notes:

-- no erosion hazard description, K-, or T-factor data available.

K Factor = unitless indicator of soil erodibility from runoff.

$K_w(\text{max})$ = Maximum K_w for shallow soils up to 18 inches deep

T Factor = Soil loss tolerance (in tons per acre).

WEG = Wind erodibility group (resistance to soil blowing in cultivated areas).

Source: USDA-SCS 1979.

3.2.2.2.2 PERMAFROST

Angyaruaq (Jungjuk) Road and Port Site

The northern half of the proposed Angyaruaq (Jungjuk) Road alignment contains intermittent permafrost in boggy soils along the Crooked Creek floodplain near the proposed mine site

(Recon 2011a). Frozen colluvial silt over weathered broken bedrock, both with occasional visible ice, is also present along slopes ascending to Juninggulra Mountain ridge lines.

Permafrost is generally absent along most of the southern half of the proposed Angyaruaq (Jungjuk) Road alignment. Where present, permafrost is generally associated with fine-grained materials and silt-bearing sand and gravel mixtures. There are few occurrences of permafrost exist north of the North Fork Getmuna Creek, and the Getmuna Creek drainage itself contains no evidence of permafrost (Recon 2011a).

Near the southern end of the proposed Angyaruaq (Jungjuk) Road, discontinuous permafrost is prevalent in low sloping, silt-bearing soils in the lower Jungjuk Creek area within 0.3 miles of the port site. Documented permafrost thicknesses in this area vary from near ground surface to 20 feet below ground surface. Visible ice volume estimates range from 1 to 50 percent (Recon 2011a).

Discontinuous permafrost at the proposed port site exists from near surface to depths greater than 35 feet (DMA 2007b; Recon 2007b). Visible ice volume estimates range from 10 to 40 percent. Fine-grained soils with moderate ice content in this area can be extremely unstable during thaw degradation conditions (Recon 2011a).

Birch Tree Crossing Road and Port Site

Discontinuous permafrost was encountered along the BTC route alternative during a mid-summer geotechnical subsurface investigation program performed in 2007 (DMA 2007a). A total of 92 test borings were completed along the alignment from Crooked Creek to mile 73.8 near the potential BTC port site. Permafrost conditions exist or have the potential to exist at approximately 60 of the 92 boring locations (65 percent). The 60 boring locations encountered frozen soil at depths greater than an assumed active layer thickness of approximately 6 to 7 feet, or had frozen soil conditions at the maximum borehole depth if less than 7 feet. Of borings advanced to depths of 10 feet or greater, approximately 45 borings exhibited frozen soil conditions at or deeper than 10 feet. Frozen soil conditions along the alignment varied from near ground surface to depths greater than 40 feet. Approximately 32 of the soil boring locations were either ice-free, or exhibited seasonal ice conditions associated with the active layer.

Similar to the proposed Angyaruaq (Jungjuk) road alignment, discontinuous permafrost is present along the Crooked Creek floodplain and flats, before the proposed alignment ascends into upland slopes and ridge tops, that are generally thawed, to approximately 10.5 miles from the proposed mine site. Intermittent permafrost conditions resume over ridge saddles, crests, and side slopes to approximately 15.5 miles from the proposed mine site. Permafrost generally becomes more prevalent under similar terrain to the Indian River floodplain crossing, located approximately 33.5 miles from the proposed mine site. The segment from Indian River floodplain crossing to Cala Poco Creek (at 40 miles) traverses segments of prevalent thermokarst terrain inundated with thick organic mat soil horizons and ice-rich, fine-grained soils.

Intermittent, discontinuous permafrost proceeds beyond the proposed Owhat River crossing, through generally flat or gradual sloping terrain that includes multiple creek floodplains, muskegs, varying degrees of thermokarst, and outwash plains. Clean sand and gravel mixtures, such as those present in the Owhat River floodplain, are often free of frozen soil conditions. Where present, permafrost conditions vary from ice-rich, silt-bearing materials to thawed

colluvium and alluvium. The presence of white massive ice was observed in silt materials in one boring located approximately 50.5 miles from the proposed mine site near the route's Owhat River crossing.

Permafrost becomes substantially more intermittent along proposed road segments between 55 and 69 miles from the proposed mine site. Ice-free borings are most common along this segment of the potential BTC alignment. Subsurface conditions indicative of permafrost again become more prevalent near the end of the alternative route terminus at approximately 73.8 miles from the proposed mine site.

Crooked Creek Winter Road

Although permafrost occurrence and distribution along the Crooked Creek Winter Road alignment has not been studied in detail, occurrence and distribution similar to documented conditions at the proposed mine site, and the proposed Jungjuk Road alignment and port site, are anticipated. Common conditions shared between these investigated areas include, but are not limited to: soil types; terrain; and topography. The temporary nature and intended purpose of the ice road is to minimize surficial disturbances.

Permafrost is most likely to be prevalent at the southern terminus of the potential Crooked Creek winter road based on similar conditions and investigations performed at the proposed Angyaruaq (Jungjuk) Port site. This includes fine-grained soils with moderate ice content, consistent with Tegguiq peat (30TQ02), and Oskawalik family (30DP03) soils. Permafrost is anticipated to extend from near surface to depths of 35 feet or greater.

Prevalent discontinuous permafrost likely exists in the low sloping topography dominated by fine-grained soils that extend north from the potential Crooked Creek terminus. Permafrost would be likely to become less prevalent and more intermittent as the landscape transitions northward to toeslopes of adjacent upland terrain, and coarser material mixtures. Furthermore, permafrost occurrence would be expected in lower valley bottoms and toeslopes of drainages, depending on soil types and slope aspects. An example would be soil type D30FPA, which is a coarse loamy alluvium associated with floodplains.

Bethel

Bethel is located near the southern extent of the discontinuous permafrost zone (Ferrians 1965, 1994). The proposed Bethel Port site is located on the western side of the Kuskokwim River, where silt and sandy silt in upland deposits contain abundant permafrost (Wilson et al. 2013), and permafrost there has been documented to depths ranging from approximately 375 to 600 feet (Dorava and Hogan 1995). At the Bethel Fuel Sales' tank-farm facility located approximately 30 feet above the west bank of the Kuskokwim River shoreline, the top of permafrost ranges from 3 feet to over 50 feet below ground surface, and the active layer ranges from approximately 3 to 6 feet in depth (Busey et al. 2000).

Dutch Harbor

Unalaska (Dutch Harbor) is located in an area that is generally considered free of permafrost (Ferrians 1965, 1994).

3.2.2.2.3 EROSION

Various geologic processes that cause erosion are described in Section 3.2.2.1.3. Factors contributing to accelerated erosion can include, but are not limited to human or animal activities or major natural events in nature such as wildfires (NRCS 2008). Erosion mechanisms typical of road construction activities include hydraulic and thermal erosion. Soil susceptibility to erosion associated with each part of the transportation facilities component is described below.

Angyaruaq (Jungjuk) Road and Port Site

Available NRCS erosion descriptions for soil map units along the proposed Angyaruaq (Jungjuk) Road alignment range from slight to severe for water-induced erosion, assuming the organic mat has been removed (NRCS 2008) (Table 3.2-3). Soil types with severe ratings for water erosion are associated with colluvium and loess on slopes. Hydraulic erosion potential would be variable along the proposed Angyaruaq (Jungjuk) Road, as slopes of varying grades and aspects are present, as well as multiple minor stream crossings (Recon 2011a). Wind erosion hazards for soils of the proposed Angyaruaq (Jungjuk) Road range from slight to severe, the latter of which are associated with loess soils and silty floodplains.

Pronounced thermal erosion would be most likely to occur in the low sloping, silt-bearing soils near the proposed Angyaruaq (Jungjuk) Port site, where discontinuous ice-rich permafrost is most prevalent. Up to 3 feet of settlement can be expected based on observed, naturally occurring thaw degradation processes (Recon 2011a). As noted below, however, the potential for thermal erosion along the Angyaruaq (Jungjuk) Road is lower than along the BTC road, as thermokarst terrain is not present along the Angyaruaq (Jungjuk) Road corridor.

Birch Tree Creek Road and Port Site

The potential for hydraulic erosion along the first 20 miles of the BTC alignment would be the same as that of the coincident Angyaruaq (Jungjuk) Road alignment in this area. Available NRCS water erosion descriptions for soil map units along the proposed BTC Road alignment range from slight to severe, assuming removal of the organic mat (NRCS 2008) (Table 3.2-3). Soil types with severe ratings for water erosion are associated with colluvium, coarse loamy materials, and loess on slopes. Wind erosion hazards for BTC Road soils range from slight to severe, the latter of which is associated with loess soils, loamy eolian deposits, and silty floodplains.

The potential for thermal erosion exists along multiple segments of the potential BTC alignment based on the presence of frozen silt-bearing soil conditions. Hummocky terrain associated with naturally occurring thermokarst conditions is present along numerous segments of the potential BTC alignment. These conditions often coincide with ice-rich fine-grained soils overlain by an appreciable organic-rich cover (DMA 2007a). Removal or disturbance of any overlying organic mat and vegetative materials can increase permafrost degradation rates and secondary effects associated with hydraulic erosion or accelerated erosion mechanisms (e.g., construction, ORVs, etc.).

Crooked Creek Winter Road

Available NRCS erosion descriptions for soil map units along the potential Crooked Creek Winter Road alignment range from slight to severe for water-induced erosion (NRCS 2008) (Table 3.2-3). Soil types with severe ratings for water erosion are associated with colluvium and loess on higher gradient slopes. NRCS (2008) water erosion ratings generally assume that the organic mat has been removed. Soils most susceptible to thermal erosion are most likely to occur in the low sloping, silt-bearing soils near the Crooked Creek Village ice road terminus where discontinuous ice-rich permafrost is likely to be most prevalent.

Bethel

No water or wind erosion classifications have been established for Bethel soil types in the literature (USDA-SCS 1979 or Hinton and Girdner 1975). Overall, soils in the Bethel area and the Kuskokwim floodplain range from poorly drained organic material over permafrost or loamy materials, to well drained stratified sand, silt, and loamy mixtures (Table 3.2-4). The Susitna soil series in the Bethel area exists on nearly level topography, and dominant gradients are generally less than one-half percent. The soils are well drained to moderately well drained (Hinton and Girdner 1967). The silty material is highly susceptible to frost action and the permafrost table is generally near the surface. Disturbance or removal of the insulative organic materials can facilitate thaw, which is often followed by subsidence and thermal erosion. Based on the dominant fine-grained composition of these soils, susceptibility to water and wind erosion is likely, dependent on localized physical conditions such as vegetation and/or disturbance, slope aspects, and soil cohesion characteristics.

Dutch Harbor

No water or wind erosion classifications have been established for Dutch Harbor soil types in the literature (USDA-SCS 1979). Surface materials in the Dutch Harbor area generally consist of unconsolidated materials that overlie shallow bedrock interface ranging in depth from 1.5 to 5 feet. The materials generally consist of glacial sediment and materials of volcanic origin (Lemke and Vanderpool 1995). Unstable and potentially unstable unconsolidated material slopes are limited to tills and undifferentiated materials over bedrock. These surface materials can be susceptible to soil failure and subsequent erosion processes during periods of heavy rainfall, where failure is attributed to the presence of till materials at depth (ADNR 1986). Since the Dutch Harbor area is located outside the geographic distribution of discontinuous permafrost, thermal erosion processes are assumed to be non-existent (Ferrians 1965).

3.2.2.2.4 SOIL QUALITY/CONTAMINATED SITES

Review of the federal CWA Impaired Water Section 303(d) listings indicated that no known impacted watersheds are present within the localities of the proposed project's transportation facilities component. Review of the CERCLIS database indicated that neither are any known federally funded Superfund sites present within proposed transportation facilities areas.

Review of the ADEC Contaminated Sites database indicated a total of 126 contaminated sites in the proposed project's transportation areas, in several communities along the Kuskokwim River corridor and in Dutch Harbor on Unalaska Island. Of these, about 50 are located within about ¼ mile of possible tank farm/port locations on the Kuskokwim River and in Dutch Harbor. Figure

3.2-4 and Figure 3.2-5 present the locations of the nearby sites, and Table 3.2-5 and Table 3.2-6 list their names and locations relative to the proposed project, as well as cleanup status.

Kuskokwim River Corridor

In the Bethel area, 38 known release sites were identified. Of these, 13 are located either within the Bethel Port site or within ¼-mile of the port site or Kuskokwim River (Table 3.2-5). Of the sites, 6 are conditionally closed, 2 are conditionally closed with institutional controls, and 5 remain in an open status. One site is located within the proposed Bethel port site boundaries. Listed as Bethel Fuel Sales (ADEC Hazard ID# 2127), this site experienced a petroleum release to the ground surface near a fill tank. Soils were excavated and landfarmed on site, and ADEC issued a Cleanup Complete status for the site.

Several sites about ½-mile northeast of the Bethel port site are within ¼-mile of the river. These sites, shown on Table 3.2-4, are cross-gradient to the proposed port site. Three additional sites associated with underground storage tanks (USTs) or fuel spills at the Bethel Hospital, were identified slightly further than ¼-mile northwest of, and hydraulically upgradient from, possible Bethel Port site locations. However, given the presence of permafrost in the area, the low gradient topography, and distance from the project site, these locations do not appear to be major potential sources of impairment to the Project Area. All other ADEC sites for the Bethel area are greater than 1 mile from the Project Area or are hydraulically cross-gradient or downgradient from the Project Area, and do not appear to pose a risk of substantial environmental impairment.

Other communities that have contaminated sites located within ¼ mile of the Kuskokwim River include Napakiak, Napaskiak, Kwethluk, Akiachak, Akiak, Tuluksak, Lower Kalskag, and Aniak. A total of 24 contaminated sites in these communities are within ¼ mile of the Kuskokwim River, and are listed in Table 3.2-5. Of these, nine are conditionally closed, one is conditionally closed with institutional controls, and 14 remain open. The source of contamination at most of the sites is primarily attributed to petroleum hydrocarbon releases. Release sources include, but are not limited to: fuel farms; above-ground storage tanks (ASTs) and USTs; and fueling systems. Fuel-impacted soil and/or groundwater conditions exist at many of the open sites. Other minor contaminants include metals and pesticides.

Two sites were listed in the CERCLIS database for the Aniak area within a ¼-mile of the river transportation corridor. One of the sites, listed as USDOI BLM Kolmakof Mine, is located on the Kuskokwim River about 20 miles upstream of Aniak, and formerly produced mercury from cinnabar. It is a federal facility and is not listed on the National Priorities List. The other site, listed as White Alice Communication-School Facility, was transferred from the Air Force to the State of Alaska and is not listed on the National Priorities List.

The Red Devil Mine located approximately 30 miles upstream of Crooked Creek (e.g., Figures 3.7-4 and 3.7-12 in Section 3.7, Water Quality) is listed in the CERCLIS database. The site is an abandoned mercury mine predominantly impaired with elevated concentrations of mercury, antimony, arsenic, and organic compounds. Impairments associated with this site pose no environmental concern to soils within localities of the proposed project's transportation facilities component. Potential waterbody influences; however, are presented in Section 3.7, Water Quality.

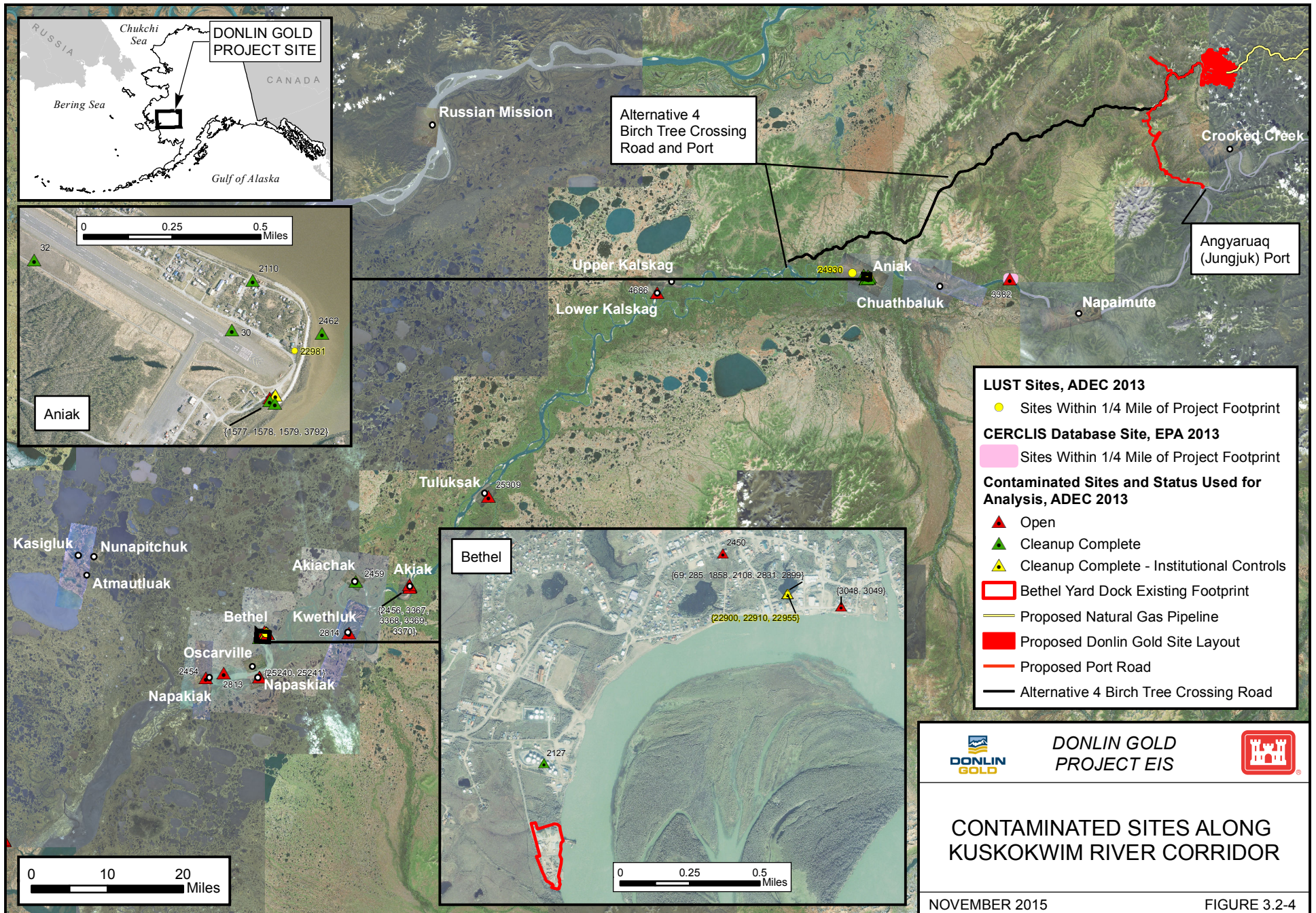


Table 3.2-5: Contaminated Sites within Kuskokwim River Corridor

ADEC Hazard ID	Site Name ¹	Distance (feet) and Direction from Kuskokwim River	Status
Bethel			
69	Bethel Airport (Former)	400' N	O
285	Bethel Fuel Sales Pumphouse	400' N	CC
1858	Bank Stabilization Project	400' N	CC
2108	ADOT&PF MarkAir - Bethel	400' N	C-IC
2127	Bethel Fuel Sales	600' W	CC
2450	Bethel Utilities Corp. Power Plant	1,300' N	O
2831	Bethel Radio Relay Station	400' N	O
2899	Bethel BIA Headquarters	400' N	C-IC
3048	AKARNG Bethel Old AAOF	100' N	CC
3049	AKARNG Bethel OMS	100' N	O
22900	FWS – Yukon Delta NWR Headquarters	400' N	CC
22910	Robair Repair – Bethel Airport	400' N	CC
22955	Bethel Public Works Yard	400' N	O
Kuskokwim Corridor – Napakiak			
2454	AKARNG Napakiak FSA	500' W	O
Kuskokwim Corridor – Napaskiak			
2813	AKARNG Napaskiak FSA	0	O
25240	Napaskiak Incorporated Store Former Tank Farm	300' SE	O
25241	Napaskiak Former BIA School Day Tanks	300' SE	O
Kuskokwim Corridor – Kwethluk			
2814	Akarng Kwethluk FSA	400' S	O
Kuskokwim Corridor – Akiachak			
2459	AKARNG Akiachak FSA	900' N	CC
Kuskokwim Corridor – Akiak			
2456	AKARNG Akiak FSA	700' W	O
3367	Akiak Elementary School Former Tank Farm	700' W	O
3368	Akiak High School Former Tank Farm	700' W	O
3369	Akiak Korarmiut Corporation Tank Farm	500' W	O
3370	Akiak Old City Tank Farm and Power Plant	1,300' W	O
Kuskokwim Corridor – Tuluksak			
25309	Tuluksak Old Power Plant	200' SW	O
Kuskokwim Corridor – Lower Kalskag			
4686	Old AVEC Tank Farm, Lower Kalskag	600' NW	O

Table 3.2-5: Contaminated Sites within Kuskokwim River Corridor

ADEC Hazard ID	Site Name ¹	Distance (feet) and Direction from Kuskokwim River	Status
Kuskokwim Corridor – Aniak			
1577	FAA Aniak Pesticide Releases	200' W	O
1578	ADOT&PF Aniak Building 301	200' W	C-IC
1579	FAA Aniak Bldg. 200 POL Releases	200' W	CC
2110	Alaska Commercial Prop. – Aniak	200' S	CC
2462	Aniak Apartments	0' W	CC
3792	IHS Aniak Clinic	100' W	CC
22981	MarkAir Facility – Aniak	200' W	CC
32	Eareckson Air Station ST34	1,300' SW	CC
30	Eareckson Air Station ST32	1,000' SW	CC
Kuskokwim Corridor – Other			
24930	FAA Aniak DF – UST 17-A-1	1,100' SW	CC
3382	BLM Kolmakof Mine	300' N	O
499	BLM Red Devil Mine Site	1,000' SW	O

Notes:

¹ Includes sites within about ¼ mile of project footprint or Kuskokwim River (Figure 3.2-4).

Abbreviations:

AAOF = Army Airfield Operations Facility
ADOT&PF = Alaska Department of Transportation & Public Facilities
AKARNG = Alaska Army National Guard
AVEC = Alaska Village Electric Corporation
ADEC = Alaska Department of Environmental Conservation

BIA = Bureau of Indian Affairs
DOC = Department of Corrections
FAA = Federal Aviation Administration
FSA = Federal Scout Armory
IHS = Indian Health Services

OMS = Organizational Maintenance Shop
NWR = National Wildlife Refuge
FWS = U.S. Fish & Wildlife Service
UST = Underground Storage Tank
YK = Indian Health Service Yukon-Kuskokwim

Site Status:

CC = Cleanup Complete C-IC = Cleanup Complete with Institutional Controls O = Open (characterization /remediation ongoing)

Source: ADEC 2013a.

A database search for the Dutch Harbor area produced 71 known contaminated sites. Search criteria were limited to the main Dutch Harbor area and did not include all sites on Unalaska Island. Currently, the Project-specific tank farm expansion site has not been chosen. However, existing tank farms and docks at Dutch Harbor, Rocky Point, and the west side of Iliuliuk Bay (Figure 3.2-5) were assumed to be likely candidates for the purposes of this analysis, as they handle ongoing fuel shipments in the area (Oasis Environmental and Kinnetic Laboratories 2006). Thus, distance and direction estimates are provided in Table 3.2-6 relative to these locations.

Of the 71 total ADEC sites listed for Dutch Harbor, 17 are located within about ¼ mile of existing tank farms and docks (Figure 3.2-5 and Table 3.2-6). Two of these are listed as cleanup complete, one as Cleanup Complete with Institutional Controls, and the rest as currently open. One site was listed on the CERCLA Database search for the Dutch Harbor area. Referred to as the Dutch Harbor Sediment Site, this site contains contaminated sediments related to numerous historic petroleum spills in and near the harbor related to fuel shipping and handling. It is not a federal facility and is not listed on the National Priorities List.

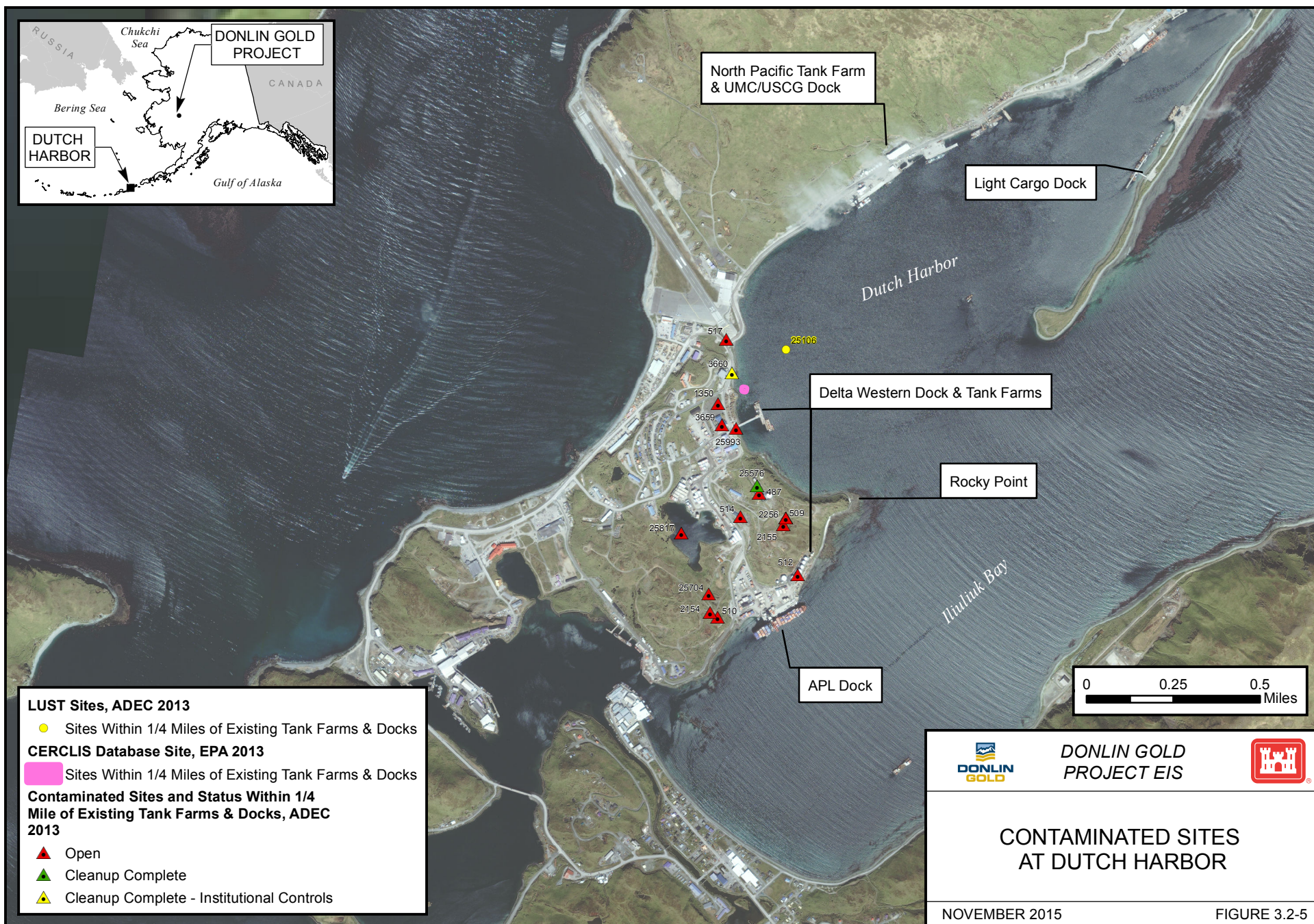


Table 3.2-6: Contaminated Sites at Dutch Harbor

ADEC Hazard ID	Site Name	Distance and Direction from Nearest Existing Tank Farms and Docks ¹	Status
3660	Dutch Harbor-Power Plant	700' NW	C-IC
517	Dutch Harbor – Aqua Fuel System #1	1,000' NW	O
25106	FAA Dutch Harbor	0	CC
25576	Delta Western Tank Farm Dutch Harbor	0	CC
25993	Delta Western Dutch Harbor Dock Pipelines	0	O
1350	Dutch Harbor- Pre WW II Tank Farm	400' NW	O
3659	Dutch Harbor- Warehouse WWII B 551	200' W	O
487	Delta Western Bulk Plant – Dutch H.	0	O
2256	Dutch Harbor- Tar Pond B Rocky Point	500' SE	O
509	Dutch Harbor- Rocky Point Tank Hill	0	O
514	Dutch Harbor- Rocky Point Thermal Treat	1,200' NW	O
25817	Dutch Harbor- Iliuliuk Lake and the Floating Pump House	1,300' SW	O
25704	Dutch Harbor- Rocky Point Bldg. 627	900' NE	O
2154	Dutch Harbor- Tar Pond A Rocky Point	800' E	O
510	Dutch Harbor- Rocky Point Tanks 17-18	800' E	O
512	Dutch Harbor – Rocky Point Lower Tank	0	O
2155	Dutch Harbor- Tar Ponds C-D Rocky Point	500' SE	O

Notes:

Includes sites within about ¼ mile of assumed tank farm expansion site at or near existing tank farms and docks (Figure 3.2-5).

ADOT&PF = Alaska Department of Transportation & Public Facilities

FAA = Federal Aviation Administration

PCR = Project Control Room

UST = Underground Storage Tank

LSA = Little South America

SREB = Snow Removal Equipment Building

ADEC = Alaska Department of Environmental Conservation

AWS = Aircraft Warning Station

NDSA = Naval Defensive Sea Area

USPS = U.S. Postal Service

Site Status:

CC = Cleanup Complete

C-IC = Cleanup Complete with Institutional Controls

O = Open (characterization /remediation ongoing)

Source: ADEC 2013a.

3.2.2.3 PIPELINE

3.2.2.3.1 SOIL TYPES

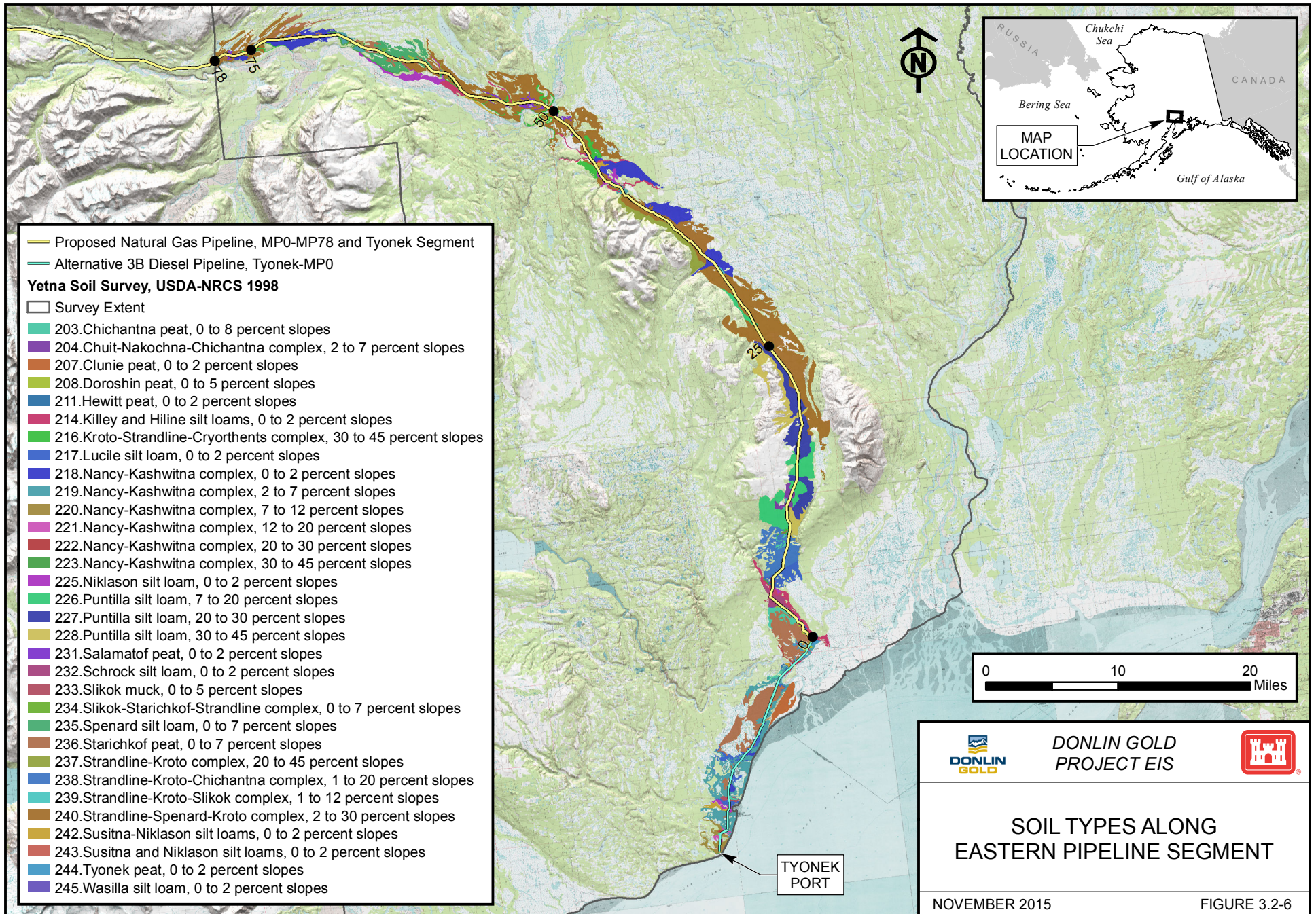
Surficial deposits and geotechnical investigations conducted by Donlin Gold along the proposed pipeline route are described in Section 3.1, Geology. Additional soil details have been compiled for the project corridor in the Pipeline Plan of Development (SRK 2013b) based on terrain mapping and geotechnical analyses as summarized in Section 3.1, Geology. These additional soil details are summarized in tabular format in Appendix F. NRCS soil types associated with the pipeline are described below.

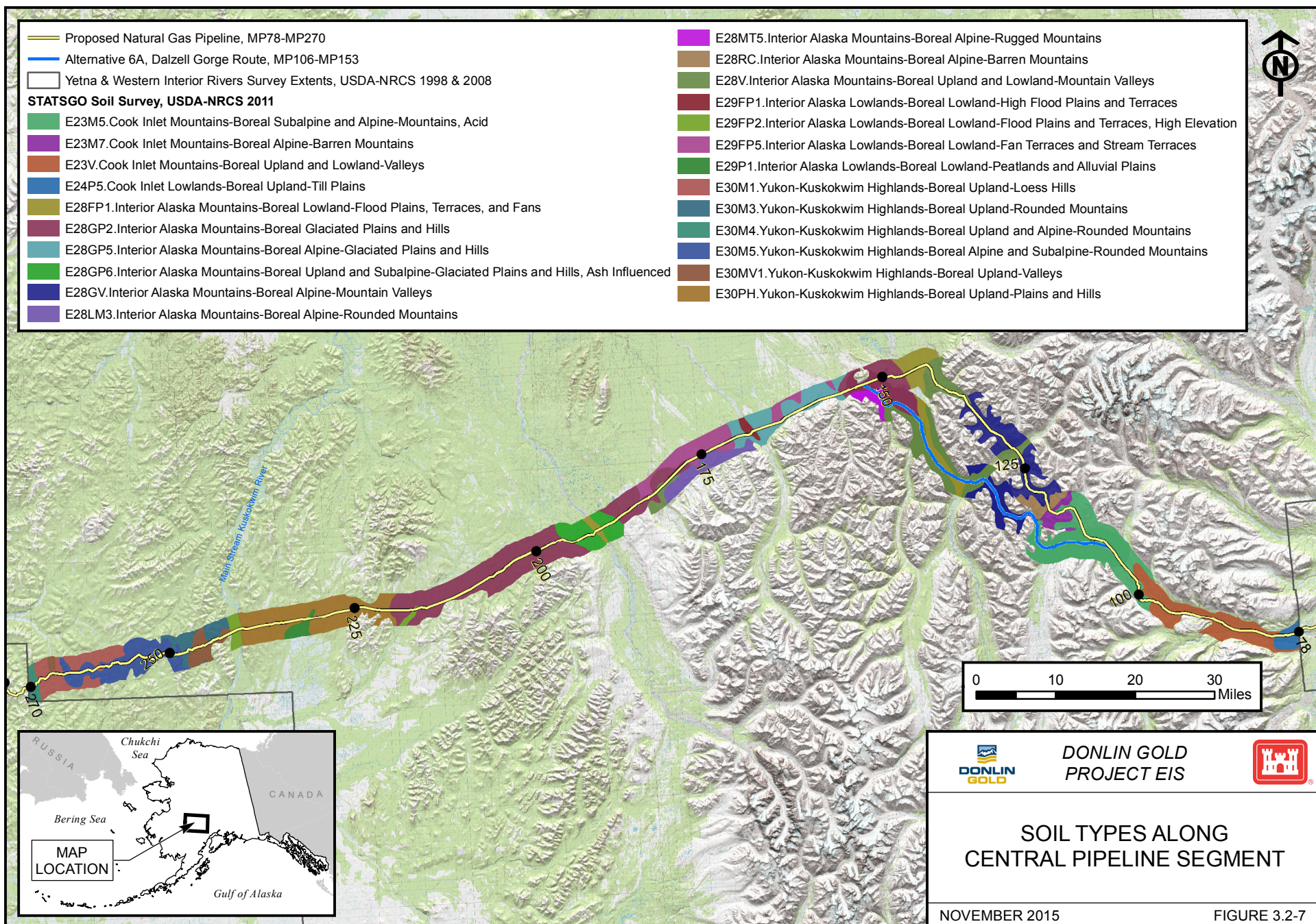
The NRCS (1998) *Soil Survey of the Yentna Area, Alaska* is the most current and detailed regional-level soils mapping resource available for the eastern segment of the proposed pipeline

alignment. Soil survey information is available from the terminus of the diesel pipeline alternative at Tyonek to milepost (MP) 0, and from MP 0 to approximately MP 78 of the eastern pipeline segment. The proposed pipeline corridor crosses about 30 different soil map units in the Yentna survey area. Map units are presented on Figure 3.2-6 and soil descriptions in Table 3.2-7.

Available soil survey coverage in the central portion of the proposed pipeline corridor is primarily limited to general-level soils information provided in the State Soil Geographic Database (STATSGO) for Alaska that is based on mapping conducted by the USDA Soil Conservation Service (SCS) in 1979 and revised in 2011 (USDA-SCS 1979, USDA 2011). This source incorporates information from major and current public-domain resource datasets for Alaska. About 20 soil map units from the STATSGO survey have been identified in the central segment of the proposed pipeline corridor. Map units are presented on Figure 3.2-7 and soil descriptions in Table 3.2-8.

The most comprehensive and current regional soils mapping resource for the western end of the proposed pipeline corridor is the NRCS (2008) *Soil Survey of the Western Interior Rivers Area, Alaska*. The area of coverage extends from approximately MP 270 to the western route terminus at the proposed mine site. Soil survey information applicable to this segment is considered reconnaissance level or detailed reconnaissance level mapping. Two soil map units from this survey have been identified along the proposed pipeline corridor (Figure 3.2-8). These are the same as those described for the proposed mine site in Section 3.2.2.1.1.





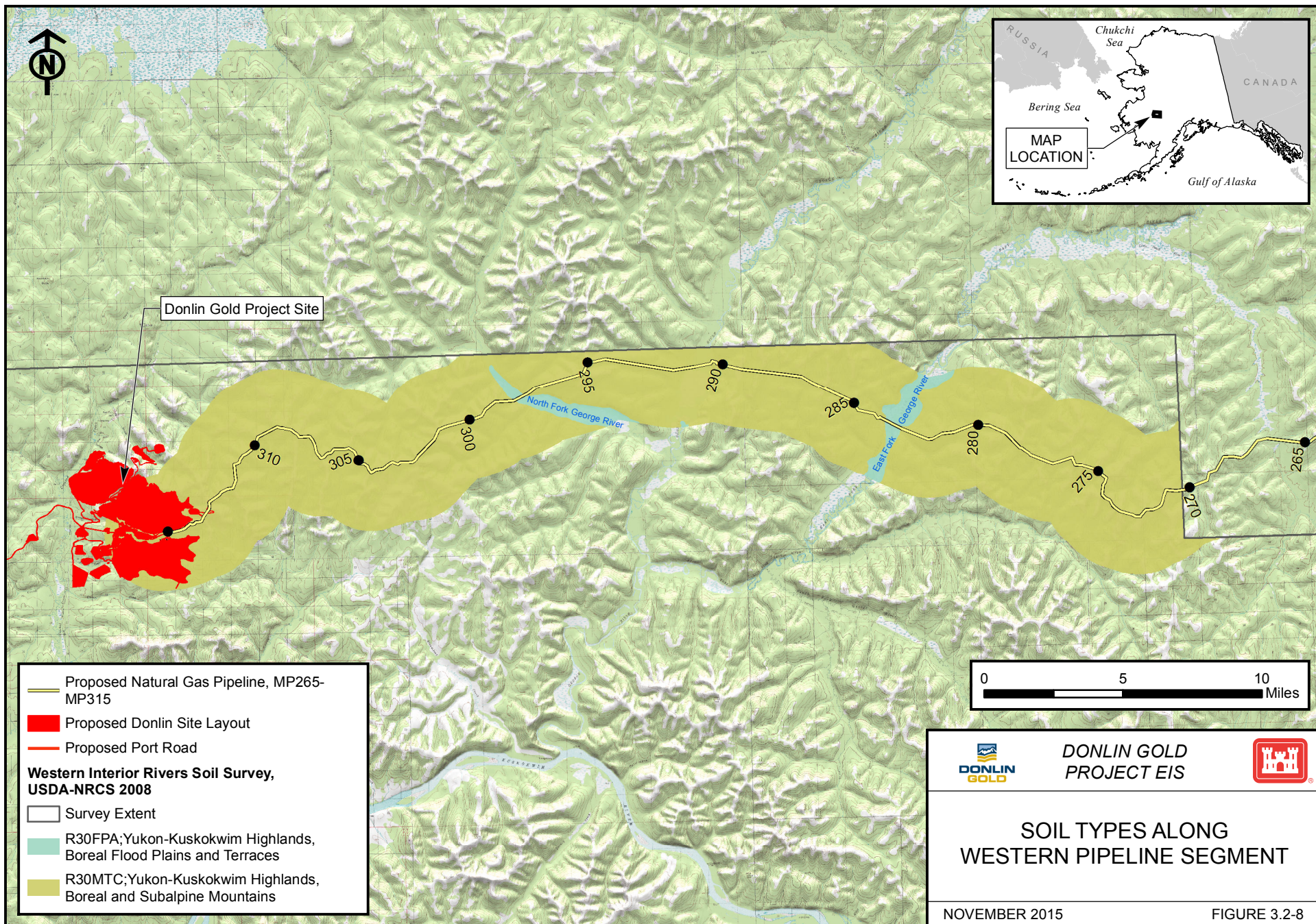


Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
203 - Chichantna peat	Euic Fluvaquentic Borosaprists	Peat deposits with interlayered with ash-influence loess	Muskegs and depressional areas	0 to 8	Very poorly drained	na	na
204 - Chuit-Nakochna-Chichantna complex							
Chuit	Medial over loamy, mixed Andic Humicryods	Ash-influenced loess deposited over massive, firm glacial till	Mountain sideslopes	2 to 7	Well drained	Slight	Severe
Nakochna	Medial, Lithic Humicryods	Ash-influenced loess deposited over bedrock	Mountain side slopes and ridges	2 to 7	Well drained	Slight	Severe
Chichantna	Euic Fluvaquentic Borosaprists	Peat deposits interlayered with ash-influenced loess	Muskegs and depressional areas	2 to 5	Very poorly drained	na	na
207 - Clunie peat	Loamy, miced, euic Terric Borofibrists	Coarse peat overlying loamy tidal sediments	Tidal flats	0 to 2	Very poorly drained; frequent flooding	na	na
208 - Doroshin peat	Loamy, miced, euic Terric Borohemists	Peat deposits over silty mineral deposits	Muskegs	0 to 5	Very poorly drained	na	na
211 - Hewitt peat	Loamy, mixed, euic Terric Borohemists	Peat over silty alluvium	Muskegs on floodplains	0 to 2	Very poorly drained; occasional flooding	Slight	Slight
214 - Killey and Hiline silt loams							
Hiline	Coarse-loamy, mixed, acid Typic Cryaquents	Alluvium	Floodplains and stream terraces	0 to 2	Very poorly drained; frequent flooding	Severe	Slight
Killey	Coarse-loamy over sandy or sandy-skeletal, mixed, acid Typic	Stratified loamy alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Very poorly drained; frequent flooding	Severe	Slight
216 - Kroto-Strandline-Cryothents complex							
Kroto	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines, hills, and mountain footslopes	30 to 45	Well drained	Severe	Severe

Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines, and mountain footslopes	30 to 40	Well drained	Severe	Severe
Cryothents	Cryothents	Firm glacial till	Escarpments on moraines, drumlins, and mountain sideslopes	35 to 45	Well drained	Severe	Severe
217 - Lucile silt loam	Medial over sandy or sandy-skeletal, mixed Andic Cryaquods	Ash-influenced loess over sandy and gravelly material	Stream terraces	0 to 2	Poorly drained	Slight	Severe
218 - Nancy-Kashwitna complex							
Nancy	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	0 to 2	Well drained	Slight	Severe
Kashwitna	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	0 to 2	Well drained	Slight	Severe
220 - Nancy-Kashwitna complex							
Nancy	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	7 to 12	Well drained	Severe	Severe
Kashwitna	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	7 to 12	Well drained	Severe	Severe
221 - Nancy-Kashwitna complex							
Nancy	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	12 to 20	Well drained	Severe	Severe
Kashwitna	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	12 to 20	Well drained	Severe	Severe

Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
222- Nancy-Kashwitna complex							
Nancy	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	20 to 30	Well drained	Severe	Severe
Kashwitna	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	20 to 30	Well drained	Severe	Severe
223- Nancy-Kashwitna complex							
Nancy	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	30 to 45	Well drained	Severe	Severe
Kashwitna	Medial over sandy or sandy-skeletal, mixed Andic Haplocryods	Ash-influenced loess overlying sandy and gravelly alluvium	Alluvial terraces	30 to 45	Well drained	Severe	Severe
225 - Niklason silt loam	Coarse-loamy over sandy or sandy-skeletal, mixed, non-acid Typic Cryofluvents	Stratified loamy material over sandy and gravelly underlying material	Floodplains, alluvial fans, and natural levees	0 to 2	Well drained; frequent flooding	Moderate	Severe
226 - Puntilla silt loam	Medial over loamy, mixed Andic Humicryods	Ash-influenced loess deposited over firm glacial till substratum	Mountain side slopes	7 to 20	Well drained	Moderate to severe	Severe
227 - Puntilla silt loam	Medial over loamy, mixed Andic Humicryods	Ash-influenced loess deposited over firm glacial till substratum	Mountain side slopes	20 to 30	Well drained	Severe	Severe
228 - Puntilla silt loam	Medial over loamy, mixed Andic Humicryods	Ash-influenced loess deposited over firm glacial till substratum	Mountain side slopes	30 to 45	Well drained	Severe	Severe
231 - Salamatoff peat	Dysic Sphagnic Borofibrists	Coarse peat deposits	Muskegs	0 to 2	Very poorly drained	na	na

Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
232 - Schrock silt loam	Medial over loamy, mixed Entic Haplocryods	Ash-influenced loess deposited over coarser textured alluvium	Stream terraces	0 to 2	Well drained	Slight	Severe
233 - Slikok muck	Coarse-silty, mixed, acid Histic Cryaquepts	Volcanic ash-influenced mineral materials over glacial till	Toeslopes of moraines, muskeg borders, and depressional areas	0 to 5	Very poorly drained	Slight to moderate	Slight
234 - Slikok-Starichkof-Strandline complex							
Slikok	Coarse-silty, mixed, acid Histic Cryaquepts	Volcanic ash-influenced mineral materials over glacial till	Footslopes of moraines and muskeg borders	0 to 5	Very poorly drained	Slight to moderate	Slight
Starichkof	Dysic Fluvaquentic Borhemists	Coarse peat containing thin stratas of mineral material	Muskegs	0 to 2	Very poorly drained	na	na
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines, and mountain footslopes	2 to 7	Well drained	Slight to moderate	Severe
235 - Spenard silt loam	Medial over loamy, mixed Andic Cryaquods	Volcanic ash-influence loess over firm glacial till substratum	Moraines and mount side slopes and footslopes	0 to 7	Very poorly drained	Moderate	Severe
236 - Starichkof peat	Dysic Fluvaquentic Borhemists	Coarse peat containing thin stratas of mineral material	Muskegs	0 to 7	Very poorly drained	na	na
237 - Strandline-Kroto complex							
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	20 to 45	Well drained	Severe	Severe
Kroto	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines, hills, and mountain footslopes	20 to 45	Well drained	Severe	Severe
238 - Strandline-Kroto-Chichantna complex							
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	3 to 20	Well drained	Moderate to severe	Severe

Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
Kroto	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	3 to 20	Well drained	Moderate to severe	Severe
Chichantna	Euic Fluvaquentic Borosaprists	Peat deposits interlayered with ash-influenced loess	Muskegs	1 to 8	Very poorly drained	na	na
239 – Strandline-Kroto-Slikok complex							
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	2 to 12	Well drained	Slight to moderate	Severe
Kroto	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	1 to 12	Well drained	Slight to moderate	Severe
Slikok	Coarse-silty, mixed, acid Histic Cryaquepts	Volcanic ash-influenced mineral materials over glacial till	Toeslopes of moraines, muskeg borders, and depressional areas	1 to 5	Very poorly drained	Slight	Slight
240 - Strandline-Spenard-Kroto complex							
Strandline	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines and mountain footslopes	5 to 30	Well drained	Slight to severe	Severe
Spenard	Medial over loamy, mixed Andic Cryaquods	Volcanic ash-influenced loess over firm glacial till substratum	Moraines, mountain side slopes and foot slopes	2 to 12	Very poorly drained	Slight to moderate	Severe
Kroto	Medial over loamy, mixed Andic Haplocryods	Ash-influenced loess overlying firm glacial till	Moraines, hills, and mountain footslopes	5 to 30	Well drained	Moderate to severe	Severe
241 - Suntrana silt loam	Medial over loamy, mixed Andic Cryaquods	Loess deposited over alluvial sediments which overlie firm glacial till	Remnant glacial moraines adjacent to Cook Inlet	2 to 7	Poorly drained	Slight to moderate	Severe

Table 3.2-7: Soil Types and Erosion Hazards Along Eastern Pipeline Segment

Soil Map Unit ¹ and Major Components	Family or Taxonomic Class	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Water	Erosion Air
242 -Susitna-Niklason silt loam							
Susitna	Coarse-loamy, loamy, mixed, non-acid Typic Cryofluvents	Stratified loamy alluvium over sand and gravel	Floodplains and alluvial terraces	0 to 2	Well drained; occasional flooding	Moderate	Severe
Niklason	Coarse-loamy over sandy or sandy-skeletal, mixed, non-acid Typic Cryofluvents	Stratified loamy material over sandy and gravelly underlying material	Floodplains, and natural levees	0 to 2	Well drained; occasional flooding	Moderate	Severe
243 – Susitna and Niklason silt loams							
Susitna	Coarse-loamy, loamy, mixed, non-acid Typic Cryofluvents	Stratified loamy alluvium over sand and gravel	Floodplains and alluvial terraces	0 to 2	Well drained; frequent flooding	Severe	Severe
Niklason	Coarse-loamy over sandy or sandy-skeletal, mixed, non-acid Typic Cryofluvents	Stratified loamy material over sandy and gravelly underlying material	Floodplains, and natural levees	0 to 27	Well drained; frequent flooding	Severe	Severe
244 - Tyonek peat	Euic Fluvaquentic Borosaprists	Organic materials interlayered with ash-influenced loess	Toeslopes of moraines	0 to 2	Very poorly drained	na	na
245 -Wasilla silt loam	Fine-loamy, mixed acid Humic Cryaquepts	Silty alluvium	Floodplains and alluvial terraces	0 to 2	Poorly drained; frequent flooding	Moderate	Severe

Notes:

Tyonek to MP 0, and MP 0 to MP 78 (Soils map units shown on Figure 3.2-6).

na = not available due to parameter insignificance.

Source: NRCS 1998.

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					K _w (max)/ T Factors	WEG
E23M5 - Cook Inlet Mountains-Boreal Subalpine and Alpine-Mountains, Acid						
E23-Boreal subalpine scrub/meadow mosaic-silty acid slopes, ash influenced and similar soils	Organic material over silty volcanic ash and/or silty eolian deposits over gravelly till derived from diorite	Mountains	15 to 35	Well drained; frequent flooding	0.37/2	1
E23-Boreal rock outcrop and rubble land	Colluvium and/or scree and/or talus	Mountains	20 to 150	na	na/na	na
E23-Boreal alpine scrub-gravelly acid colluvial slopes and similar soils	Organic material over silty volcanic ash over gravelly colluvium derived from diorite	Mountains	20 to 65	Well drained; frequent flooding	0.24/3	6
E23M7 - Cook Inlet Mountains-Boreal Alpine-Barren Mountains						
E23-Boreal rock outcrop and rubble land	Colluvium and/or scree and/or talus	Mountains	20 to 150	na	na/na	na/na
Boreal permanent snow and ice	Permanent snow and ice	Mountains	20 to 150	na	na/na	na/na
E23V - Cook Inlet Mountains-Boreal Upland and Lowland-Valleys						
E23-Boreal subalpine scrub/meadow mosaic-silty till slopes, ash influenced and similar soils	Organic material over silty volcanic ash and/or silty eolian deposits over gravelly till derived from diorite	Mountains	15 to 35	Well drained; frequent flooding	0.37/2	1
E23-Boreal forest-silty till slopes, ash influenced and similar soils	Organic material over silty volcanic ash and/or silty eolian deposits over gravelly till	Mountains	15 to 35	Well drained; frequent flooding	0.37/2	1
E23-Boreal forest-silty till slopes, ash influenced and similar soils	Organic material over ash-influenced silty eolian deposits over gravelly till	Hills, mountains	5 to 30	Well drained; frequent flooding	0.43/5	2
E24P5 - Cook Inlet Lowlands-Boreal Upland-Till Plains						
E24-Boreal forest-silty till slopes, moderately thick, ash influenced and similar soils	Organic material over ash-influenced silty eolian deposits over gravelly till	Hills, mountains	2 to 28	Well drained; frequent flooding	0.43/5	2

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					$K_w(\text{max}) / T$ Factors	WEG
E24-Boreal forest-silty till slopes, moderately wet, ash influenced and similar soils	Organic material over ash-influenced silty eolian deposits over glacial gravelly till	Hills, plains	4 to 6	Very poorly drained; frequent flooding	0.43/5	8
E24-Boreal scrub/sphagnum-organic depressions and similar soils	Organic material	Depressions on plains	0 to 1	Very poorly drained; frequent flooding	na/2	8
E28FP1 - Interior Alaska Mountains-Boreal Lowland-Floodplains, Terraces and Fans						
E28-Boreal rock outcrop and rubble land	Sandy gravel and alluvium	Floodplains	0 to 2	na	0.02/na	na
E28-Boreal scrub-gravelly floodplains and similar soils	Stratified sandy and silty alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Somewhat poorly drained; frequent flooding	0.28/3	7
E28-Boreal taiga-loamy frozen terraces and similar soils	Mossy organic material over silty eolian deposits over stratified sandy and silty alluvium	Stream terraces	0 to 1	Poorly drained; no flooding	0.32/2	8
E28-Boreal taiga/tussock-silty frozen terraces and similar soils	Organic material over sandy and silty cryoturbate	Turf hummocks on stream terraces	0 to 1	Very poorly drained; no flooding	na/2	8
E28-Boreal forest-loamy high floodplains and similar soils	Mossy organic material over stratified sandy and silty alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Well drained; rare flooding	0.28/1	7
E28GP2 - Interior Alaska Mountains-Boreal Glaciated Plains and Hills						
E28-Boreal taiga-gravelly frozen till slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly till	Hills, till plains	2 to 16	Poorly drained; no flooding	0.37/2	8
E28-Boreal forest-silty wet till slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly till	Hills, till plains	0 to 10	Poorly drained; no flooding	0.43/1	2
E28-Boreal forest-gravelly till slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly till	Hills, till plains	4 to 25	Well drained; no flooding	0.43/3	2

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					K _{w (max)} / T Factors	WEG
E28GP5 – Interior Alaska Mountains-Boreal Alpine-Glaciated Plains and Hills						
E28- Boreal alpine scrub-gravelly till slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly till	Hills, plains	14 to 35	Well drained; no flooding	0.43/3	2
E28GP6 – Interior Alaska Mountains-Boreal Upland and Subalpine-Glaciated Plains and Hills, Ash Influenced						
E28-Boreal forest-ashy till slopes and similar soils	Mossy organic material over silty volcanic ash and/or silty eolian deposits over gravelly till	Hills, plains	10 to 25	Well drained; no flooding	0.37/1	5
E28-Boreal forest-ashy wet till slopes and similar soils	Organic material over loamy volcanic ash over gravelly drift	Hills, depressions on till plains	4 to 24	Very poorly drained; no flooding	0.43/4	2
E28-Boreal subalpine scrub-meadow – ashy till slopes and similar soils	Silty volcanic ash and/or silty eolian deposits over gravelly till	Hills	4 to 28	Well drained; no flooding	0.43/2	5
E28GV - Interior Alaska Mountains-Boreal Alpine-Mountain Valleys						
E28-Boreal alpine scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium derived from shale	Mountains	25 to 75	Well drained; no flooding	0.43/3	5
E28-Boreal alpine dwarf scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium derived from volcanic and sedimentary rock	Mountains	25 to 75	Well drained; no flooding	0.43/3	5
E28-Boreal forest-silty wet till slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly till	Mountains	0 to 4	Poorly drained; no flooding	0.43/1	2
E28LM3 – Interior Alaska Mountains-Boreal Alpine-Rounded Mountains						
E28-Boreal alpine dwarf scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 65	Well drained; no flooding	0.43/3	5
E28-Boreal alpine dwarf scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 65	Well drained; no flooding	0.43/1	2
E28-Boreal alpine scrub-sedge-gravelly frozen slopes and similar soils	Organic material and/or organic material over silty eolian deposits over gravelly residuum	Mountains	0 to 25	Poorly drained	0.37/1	8

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					$K_w(\text{max}) / T$ Factors	WEG
E28-Boreal rock outcrop and rubble land	Colluvium and/or scree and/or talus	Mountains	5 to 40	na	na/na	na
E28-Boreal alpine tussock-scrub-silty frozen slopes and similar soils	Organic material over silty cryoturbate	Mountains, turf hummocks	0 to 10	Very poorly drained	0.32/2	8
E28RC - Interior Alaska Mountains-Boreal Alpine-Barren Mountains						
E28—Boreal alpine rock outcrop and rubble land	na	Mountains	0 to 100	na	na/na	na
E28V - Interior Alaska Mountains-Boreal Upland and Lowland-Mountain Valleys						
E28-Boreal forest-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over sandy and gravelly colluvium	Mountains	2 to 60	Well drained; no flooding	0.37/1	2
E28-Boreal forest-gravelly wet colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 45	Somewhat poorly drained; no flooding	0.43/1	2
E28-Boreal taiga-loamy eolian frozen slopes and similar soils	Boreal taiga-loamy eolian frozen slopes and similar soils	Mountains	0 to 24	Poorly drained; no flooding	0.43/2	8
E29FP1 – Interior Alaska Lowlands-Boreal Lowland-High Floodplains and Terraces						
E29-Boreal taiga-loamy frozen terraces and similar soils	Organic material and/or mossy organic material over silty eolian deposits over sandy and silty alluvium	Stream terraces	0 to 2	Poorly drained; no flooding	0.32/2	8
E29-Boreal scrub-loamy low floodplains and similar soils	Stratified sandy and silt alluvium	Floodplains	0 to 2	Poorly drained; frequent flooding	0.64/5	1
E29-Boreal forest-loamy floodplains and similar soils	Mossy organic material over stratified sandy and silty alluvium	Floodplains	0 to 2	Moderately well drained; occasional flooding	0.64/5	2
E29-Boreal wet meadow-loamy depressions and similar soils	Organic material over loamy alluvium	Channels on floodplains, depressions on floodplains, terraces	0 to 2	Very poorly drained; occasional flooding	0.43/5	8

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					K _{w (max)} / T Factors	WEG
E29FP2 - Interior Alaska Lowlands-Boreal Lowland-Floodplains and Terraces, High Elevation						
E29-Boreal taiga-loamy frozen terraces and similar soils	Mossy organic material over silty eolian deposits over stratified sandy and silty alluvium over sandy and gravelly alluvium	Stream terraces	0 to 2	Poorly drained; no flooding	0.37/1	8
E29-Boreal forest-loamy floodplains and similar soils	Mossy organic material over stratified sandy and silty alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Well drained; rare flooding	0.28/2	7
E29-Boreal forest-loamy frozen floodplains and similar soils	Organic material and/or organic material over stratified sandy and silty alluvium	Floodplains	0 to 2	Poorly drained; rare flooding	0.28/1	5
E29-Boreal forest-loamy low floodplains and similar soils	Mossy organic material over stratified sandy and silty alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Somewhat poorly drained; occasional flooding	0.28/2	1
E29FP5 - Interior Alaska Lowlands-Boreal Lowland-Fan Terraces and Stream Terraces						
E29-Boreal taiga-loamy frozen terraces and similar soils	Organic material and/or mossy organic material over silty eolian deposits over stratified sandy and silty alluvium over sandy and gravelly alluvium	Stream terraces	0 to 2	Poorly drained; no flooding	0.37/1	8
E29-Boreal forest-gravelly terraces and similar soils	Organic material over silty eolian deposits over sandy and gravelly alluvium	Stream Terraces	0 to 2	Somewhat excessively drained; no flooding	0.43/1	2
E29-Boreal forest-loamy frozen floodplains and similar soils	Organic material and/or mossy organic material over loamy alluvium	Floodplains	0 to 2	Poorly drained; rare flooding	0.32/1	5
E29-Boreal taiga-loamy frozen channels and similar soils	Organic material and/or mossy organic material over sandy and silty alluvium	Channels on stream terraces	0 to 2	Very poorly drained; no flooding	0.32/2	8
E29P1 - Interior Alaska Lowlands-Boreal Lowlands-Peatlands and Alluvial Plains						
E29-Boreal forest-loamy floodplains and similar soils	Mossy organic material and/or stratified sandy and silty alluvium	Floodplains	0 to 2	Moderately well drained; occasional flooding	0.64/5	2

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					$K_w (max) / T$ Factors	WEG
E29-Boreal wet meadow-organic plains and similar soils	Organic material and/or mossy organic material	Plains	0 to 1	Very poorly drained; frequent flooding	na/1	8
E29-Boreal taiga-loamy frozen terraces and similar soils	Organic material and/or mossy organic material over silty eolian deposits over stratified sandy and silty alluvium	Plains	0 to 4	Poorly drained; no flooding	0.32/2	8
E29-Boreal taiga-organic frozen peat plateaus and similar soils	Organic material and/or mossy organic material	Peat plateaus on plains	0 to 3	Well drained; no flooding	na/1	5
E30M1 - Yukon Kuskokwim Highlands-Boreal Upland-Loess Hills						
E30-Boreal taiga-silty frozen loess slopes and similar soils	Organic material and/or mossy organic material over silty eolian deposits	Hills	0 to 25	Poorly drained; no flooding	0.43/1	8
E30-Boreal forest-silty loess slopes and similar soils	Mossy organic material over loamy eolian deposits over schist or acid igneous gravelly colluvium	Hills	0 to 30	Well drained; no flooding	0.43/3	2
E30-Boreal taiga/tussock-silty frozen slopes and similar soils	Organic material over silty cryoturbate	Turf hummocks on hills	0 to 10	Very poorly drained; no flooding	0.32/2	8
E30-Boreal scrub-silty frozen drainage ways and similar soils	Organic material and/or mossy organic material over silty alluvium	Drainage ways on hills, plains	0 to 2	Very poorly drained; frequent flooding	0.28/2	5
E30M3 - Yukon Kuskokwim Highlands-Boreal Upland-Rounded Mountains						
E30-Boreal forest-silty slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly colluvium	Mountains	4 to 20	Well drained; no flooding	0.64/2	2
E30-Boreal taiga-loamy frozen colluvial slopes and similar soils	Organic material over loamy colluvium	Mountains	2 to 30	Poorly drained; no flooding	0.28/2	8
E30M4 - Yukon Kuskokwim Highlands-Boreal Upland and Alpine-Rounded Mountains						
E30-Boreal forest-silty slopes and similar soils	Mossy organic material over silty eolian deposits over gravelly colluvium	Mountains	4 to 35	Well drained; no flooding	0.64/2	2

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					$K_w (max) / T$ Factors	WEG
E30-Boreal alpine scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 35	Well drained; no flooding	0.43/3	5
E30-Boreal taiga-loamy frozen colluvial slopes and similar soils	Organic material over loamy colluvium	Mountains	2 to 34	Poorly drained; no flooding	0.37/2	8
E30M5 - Yukon Kuskokwim Highlands-Boreal Alpine and Subalpine-Rounded Mountains						
E30-Boreal alpine scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 60	Well drained; no flooding	0.43/3	5
E30-Boreal alpine dwarf scrub-gravelly colluvial slopes and similar soils	Organic material over silty eolian deposits over gravelly colluvium	Mountains	5 to 55	Well drained; no flooding	0.43/3	5
E30Boreal subalpine woodland-gravelly colluvial slopes and similar soils	Organic material over gravelly colluvium	Hills	5 to 60	Well drained; no flooding	0.37/2	3
E30MV1 - Yukon-Kuskokwim Highlands-Boreal Upland-Valleys						
E30-Boreal taiga-silty frozen colluvial slopes and similar soils	Organic material and/or organic material over schist or acid igneous silty colluvium	Mountains	2 to 20	Poorly drained; no flooding	0.43/2	8
E30-Boreal tussock-scrub-silty frozen colluvial slopes and similar soils	Organic material over silty colluvium	Turf hummocks on mountains	0 to 8	Very poorly drained; no flooding	0.32/2	8
E30-Boreal forest-loamy floodplains and similar soils	Mossy organic material over stratified sandy and silty alluvium over sandy and gravelly alluvium	Floodplains	0 to 2	Well drained; rare flooding	0.28/2	7
E30-Boreal taiga-organic frozen peat plateaus and similar soils	Organic material and/or mossy organic material	Hills, plains	0 to 3	Well drained; no flooding	na/1	5
E30PH - Yukon-Kuskokwim Highlands-Boreal Upland-Plains and Hills						
E30-Boreal taiga-silty frozen loess slopes and similar soils	Organic material and/or mossy organic material over silty eolian deposits	Hills, plains	0 to 20	Poorly drained; no flooding	0.43/1	8

Table 3.2-8: Soil Types and Erodibility Data for Central Pipeline Segment

Soil Map Unit and Major Components	Parent Material Description	Landscape Position	Slope Range (%)	Drainage Class	Erosion Factors	
					K_w (max) / T Factors	WEG
E30-Boreal taiga/tussock-silty frozen slopes and similar soils	Organic material over silty cryoturbate	Turf hummocks on plains	0 to 12	Very poorly drained; no flooding	0.32/2	8
E30-Boreal forest-silty loess slopes and similar soils	Organic material and/or mossy organic material over silty eolian deposits over gravelly colluvium	Hills	10 to 25	Well drained; no flooding	0.43/3	2

Notes:

Includes Alaska Range, north front of Alaska Range, and eastern Kuskokwim Mountains, MP 78 to MP 270 (Figure 3.2-7).

K_w (max) Factor = maximum K-factor for shallow soils up to 18 inches below surface, unitless. K-Factor is an index (measure) of soil erodibility from run-off. Higher values represent greater erodibility.

T Factor = Soil loss tolerance (sustainable loss in annual tons per acre). Lower values generally correspond to thinner, more erosion-susceptible soils.

WEG = Wind erodibility group (resistance to soil blowing in cultivated areas). Lower values represent increased erosion susceptibility.

na = applicable to soil type (e.g., rock, ice)

Source: STATSGO data; USDA-NRCS 2011, 2013.

3.2.2.3.2 PERMAFROST

Permafrost Distribution

Most of the proposed pipeline route is located in the discontinuous permafrost zone of Alaska. The Cook Inlet-Susitna Lowlands are generally considered to be free of permafrost, although sporadic isolated masses are known to occur (Ferrians 1965, 1994; Jorgenson et al. 2008). In 2010 and 2013, geotechnical studies were conducted along the proposed pipeline corridor to investigate soil and permafrost baseline conditions and establish a ground temperature monitoring program. At select locations where permafrost conditions were encountered, tubing was installed in 66 borings for placing thermistor strings to measure ambient ground temperature (CH2MHill 2011b; BGC 2013c). Ground temperature data was acquired and evaluated from at least 45 of the 66 borings equipped for ground temperature acquisition.

Based on these investigations, the estimated total length of alignment where permafrost conditions are expected to exist is approximately 31 miles (CH2MHill 2011b; BGC 2013c; Fueg 2014). Permafrost occurrence and associated thaw-stable and thaw-unstable conditions are shown on Figure 2.3-34 (Chapter 2, Alternatives). The total estimated length of thaw-unstable soil conditions along the alignment is approximately 12 miles; these are locations where soils are expected to settle more than 1 foot when thawed, over time, between 4 and 25 feet in depth. The total estimated length of thaw-stable soils along the length of the alignment is approximately 19 miles. These are mostly coarse-grained areas where soils are not expected to settle appreciably when thawed. Frozen soils encountered in borings only in the top few feet were assumed to be seasonal and were not counted in these totals unless they extended deeper. There are about 258 mapped transitions between thaw-unstable soils and either thaw-stable or non-permafrost soils, where differential thaw settlement is more likely to occur.

The ground temperature data collected along the proposed pipeline route indicate warm permafrost soil conditions ranging from 31° to 32° Fahrenheit. The narrow temperature range is indicative of a fragile equilibrium, and the isothermal nature of the data suggests ongoing thermal degradation or near degradation conditions (CH2MHill 2011b).

Permafrost is notably absent on floodplains and rivers throughout much of the proposed route, and is absent from the proposed pipeline start at Cook Inlet to approximately MP 100 in the upper Skwentna River Valley. Permafrost occurrence in the Alaska Range is discontinuous, and exists in both thaw-stable form and ice-rich thaw-unstable form. Many of the frozen soils are associated with mass wasting or alluvial fan deposits (BGC 2013a).

Thaw-unstable permafrost is most prevalent along the north flank of the Alaska Range from about MP 150 to MP 215. Numerous areas of ice-rich soil are present in this area, typically associated with fine-grained till deposits. The area west of the Big River includes hummocky hills, braided floodplain channels, and glacial till outwash that contain discontinuous permafrost consisting of ice-rich silt, sand, and gravel mixtures with localized occurrences of appreciable clay fractions (CH2MHill 2011b).

Permafrost soil conditions are generally absent from MP 215 to the route terminus at the proposed mine site, although intermittent ice-poor permafrost conditions may be present in fine-grained silt along ridgetops of the Kuskokwim Mountains. While the active layer may be greater than 6 feet at these locations due to the lack of organic cover, thaw settlement is likely limited due to the shallow depth of weathered bedrock (CH2MHill 2011b).

Seasonal freeze depth along the alignment is variable and is often influenced by insulative conditions attributed to peat-rich vegetative surface cover and snow cover. The active layer depth in areas of thick vegetative cover is generally less than 2 feet, and may be up to 6 or more feet deep in areas with mineral-rich soil.

3.2.2.3.3 EROSION

Processes

Various geologic processes that cause erosion are described in Sections 3.2.2.1.3 and 3.2.2.2.3. Primary erosion mechanisms attributed to pipeline construction activities include hydraulic erosion and thermal erosion. The potential for each are present throughout the alignment, and coincide along numerous pipeline segments. Slope length and steepness significantly influence hydraulic soil erosion rates (Warren et al. 1989), and slopes of various grades and aspects are prevalent along the proposed pipeline corridor, including sloped approaches to numerous waterbody crossings (CH2MHill 2011b). Surficial organics and peat are present over much of the proposed alignment, and because much of the route is underlain by erosion-susceptible non-cohesive soils, disturbances to the overlying protective organics can influence hydraulic and thermal erosion processes.

Thermal erosion of ice-rich, thaw unstable permafrost soils can result in ground subsidence, slope instability and drainage alteration. Although natural permafrost degradation processes exist along the proposed alignment, disturbance of insulative properties associated with surface organics will increase thermal erosion rates, leading to an increased active layer with ongoing freeze-thaw conditions throughout the year. Pipeline segments with fine-grained thaw unstable permafrost conditions would be more vulnerable to thermal erosion processes, secondary

hydraulic erosion, and accelerated erosion scenarios (e.g.-construction, off-road vehicles [ORVs], etc.). The occurrence of these conditions at proposed pipeline stream crossings, where open cut construction techniques could expose soil particularly vulnerable to both thermal and hydraulic erosion, is presented at the end of this section.

Other ice related physical processes that may influence soil erosion includes the adverse formation of seasonal ice on ground surfaces. Successive freezing of water on ground surfaces from surface or groundwater sources (e.g., seeps) during winter months can result in a layered buildup and propagation of ice. This process is referred to as aufeis formation, or annual winter glaciation. Aufeis formation on ground surfaces is generally associated with seeps or springs daylighting at ground surface. Seeps often occur along toeslopes at or near valley bottoms where unique shallow subsurface conditions exist such as permafrost or other impermeable material (e.g., clay, hardpan, etc.). Surface disturbances (slope cuts) or man-made structures can sometimes induce or augment aufeis formation through changes in surface water or groundwater flow conditions. Aufeis formation can potentially influence erosion through episodic alteration of surface water drainage patterns and prolonged soil saturation through ice-water melt runoff. Aufeis formation is anecdotally reported to occur between MP 90 through MP 97 along sloped sections of the Iditarod National Historic Trail. The most prominent drainage for aufeis formation occurrence is the Big River floodplain (CH2MHill 2011b). Aufeis formation within streams or drainages is also referred to as overflow, and is derived from stream water upwelling under pressure through frozen surfaces. Additional discussion regarding this type of aufeis formation is presented in Section 3.5, Surface Water Hydrology.

Distribution

NRCS provides a measure of water and wind erosion susceptibility for different soil types. Erosion hazards for soil map units that coincide with the eastern portion of the proposed pipeline are summarized in Table 3.2-7 (NRCS 1998). Descriptions range from slight to severe for water-caused erosion, assuming the organic mat has been removed. Soil types with severe ratings for water erosion are generally associated with silt loam on floodplains, steep mountain slopes, and moraines. Wind erosion hazards for the proposed pipeline corridor range from slight to severe, the latter generally associated with mountain slopes, ridges, alluvial terraces, and moraines.

Available erosion data for the central portion of the pipeline are summarized in Table 3.2-8 (USDA-NRCS 2013). These are based on STATSGO data and include values for soil erodibility (K-Factor), soil loss tolerance (T-factor), and WEG, described in Section 3.2.2.1.3.

Soil map units associated with the western portion of the pipeline alignment are located within the mapped area of the *Western Interior Rivers Soil Survey, Alaska* (NRCS 2008). The map units in this area (Figure 3.2-8) are the same as those described in Section 3.2.2.1.3 for the proposed mine site. Erosion descriptions by water for each of these units are provided in Table 3.2-1, and range from slight to severe, the latter of which is associated with colluvial slopes. Wind erosion hazards for these soils are rated slight to moderate.

Pipeline segments with fine-grained thaw unstable permafrost conditions (Figure 2.3-34, Chapter 2, Alternatives) would be more vulnerable to thermal erosion processes and secondary effects associated with hydraulic erosion. Stream crossings in permafrost terrain were screened for soil types particularly vulnerability to erosion by reviewing geotechnical borehole details at each of the coincident locations. Of roughly 400 proposed stream crossings, about 80 are located

in permafrost soils; these are listed in Table 3.2-9. Of these, about 30 are associated with fine-grained soils considered particularly vulnerable to erosion, and about 20 of those have known or potential fish habitat. Streams with an overall rating of moderate to high permafrost erosion concerns, including those with potential fish habitat, are highlighted in orange and peach in Table 3.2-9, and those with moderate overall ratings are highlighted in blue. Rationale used in the ratings is provided in the table key following the tabularized data. Fish have been documented at eight of the stream crossings with an overall moderate-high rating (OtterTail 2013). These include a Jones Creek tributary, Middle Fork Kuskokwim River and several tributaries to this river, and two tributaries to Tatlawiksuk River.

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Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 108	sHA3	Happy River	Skwentna	GP-002-J: OL(0.3')/SP	- (7)	stable	- (7)	L	mostly sand	Chinook salmon, Dolly Varden, slimy sculpin	yes	H
MP 113	sTMT17	Threemile Creek tributary 17	Skwentna	GP-015-J: SW	-	stable	-	L	sand and gravel	no defined channel - wetland	yes	L
MP 113	sTMT16	Threemile Creek tributary 16	Skwentna	GP-015-J: SW	-	stable	-	L	sand and gravel	no defined channel - dry (Sept)	no	L
MP 115	sTMT12	Threemile Creek tributary 12	Skwentna	GP-100-J: SP	-	stable	-	L	sand and gravel	no fish found	yes	L-M
MP 115	sTMT11	Threemile Creek tributary 11	Skwentna	GP-100-J: SP and GP-021-J: GP	-	unstable	-	L	sand and gravel	no fish found	yes	L-M
MP 115	sTMT99	Threemile Creek tributary 99	Skwentna	GP-101-J: GP/ML(2.2')/GW and GP-022-J: SW	-	stable	-	M-H	thick silt in between gravel in 1 of 2 borings	no fish found	yes	L-M
MP 115	sTMT10	Threemile Creek tributary 10	Skwentna	GP-101-J: GP/ML(2.2')/GW and GP-022-J: SW	-	stable	-	M-H	thick silt in between gravel in 1 of 2 borings	no fish found	yes	L-M
MP 116	sTMT9	Threemile Creek tributary 9	Skwentna	GP-022-J: GW	-	stable	-	L	silty gravelly sand	no fish found	yes	L-M
MP 117	sTMT5	Threemile Creek tributary 5	Skwentna	GP-026-J: SM	-	unstable	-	L	mostly gravel	no defined channel - dry (Sept)	no	L
MP 117	sTMT3	Threemile Creek tributary 3	Skwentna	GP-027-J: SM	-	stable	-	L	gravelly silty sand	no defined channel - dry (Sept)	no	L
MP 119	kTAT30	Tatina River tributary 29	Kuskokwim	GP-030-J and GP-106-J: GW	-	unstable	-	L	mostly gravel	no defined channel - wetland	yes	L
MP 120	kTAT29	Tatina River tributary 29	Kuskokwim	GP-033-J: SW and GP-034-J: GW	-	unstable	-	L	mostly gravel	no fish found	yes	L-M
MP 120	kTAT28	Tatina River tributary 28	Kuskokwim	GP-109-J and GP-033-J: SW	-	stable	-	L	sand and gravel	defined channel - dry (Sept)	no	L
MP 120	kTAT27, kTAT27_O H1	Tatina River tributary 27	Kuskokwim	GP-035-J: SM and GP-109-J: SW	-	unstable	-	L	silty sand and gravel	no defined channel-dry at crossing; no fish found at nearby optimum habitat	no at crossing; yes at nearby optimum habitat	L-M
MP 122	kTAT20	Tatina River tributary 20	Kuskokwim	GP-040-J: ML(1.5')/GW	-	stable	-	H	thick silt	no defined channel - wetland	yes	L
MP 130	kJNT41	Jones Creek tributary 41	Kuskokwim	GP-059-J: ML(1')/SP	-	stable	-	L-M	thin-moderately thin silt	defined channel - dry (Sept)	no	L
MP 130	kJNT40	Jones Creek tributary 40	Kuskokwim	GP-059-J: ML(1')/SP	-	stable	-	L-M	thin-moderately thin silt	defined channel - dry (Sept)	no	L
MP 131	kJNT39	Jones Creek tributary 39	Kuskokwim	GP-059-J: ML(1')/SP	-	stable	-	L-M	thin-moderately thin silt	no fish found	yes	L-M
MP 139	kJNT12	Jones Creek tributary 12	Kuskokwim	GP-076-J: SM	-	unstable	-	L	sand and thin silt	no defined channel - dry (Sept)	no	L
MP 139	kJNT11	Jones Creek tributary 11	Kuskokwim	GP-077-J: SP	-	stable	-	L	sand and gravel	no defined channel - dry (Sept)	no	L

Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 140	kJNT10	Jones Creek tributary 10	Kuskokwim	GP079-J: ML(2')/SM	-	unstable (North bank only)	-	H - North bank, L - South bank	thick silt	Dolly Varden	yes	H
MP 140	kJNT9	Jones Creek tributary 9	Kuskokwim	GP-79-J: ML(1.5')/SM and GP-80-J: SW/SP	-	stable	-	M-H	thick silt in 1 of 2 borings	no defined channel - dry (Sept)	no	L
MP 141	kJNT8	Jones Creek tributary 8	Kuskokwim	GP-081-J: ML(0.8')/SW	-	stable	-	L	thin silt	defined channel - dry (Sept)	no	L
MP 141	kJNT7	Jones Creek tributary 7	Kuskokwim	GP-081-J: ML(0.8')/SW	-	stable	-	L	thin silt	no defined channel - dry (Sept)	no	L
MP 143	kSFT80	South Fork Kuskokwim River tributary 80	Kuskokwim	GP-084-J: ML(5'+)	-	stable (North bank only)	-	H	thick silt	defined channel - dry (Sept)	No	L
MP 143	kSFT79	South Fork Kuskokwim River tributary 79	Kuskokwim	GP-084-J: ML(5'+)	-	stable	-	H	thick silt	defined channel - dry (Sept)	No	L
MP 144	kSFT78	South Fork Kuskokwim River tributary 78	Kuskokwim	GP-084-J: ML(5'+)	-	unstable	-	H	thick silt	defined channel - dry (Sept)	No	L
MP 148	kSFT57	South Fork Kuskokwim River tributary 57	Kuskokwim	GP-092-J: PT/OL	-	stable	-	M-H	thick organic silt	no defined channel - wetland	yes	L
MP 153	kSFT23	South Fork Kuskokwim River tributary 23	Kuskokwim	none	Bog silt (>2') over alluvial fan	unstable (East bank only)	slight/slight	M-H	thick silt potential	no fish found, defined channel, winter dry	yes	L-M
MP 153	kSFT24	South Fork Kuskokwim River tributary 24	Kuskokwim	GP212: OL (2.5')/CL		stable	slight/slight	M-H	thick organic silt	defined channel - dry (Sept)	no	L, but potential downstream effects in breakup
MP 153	kSFT43	South Fork Kuskokwim River tributary 43	Kuskokwim	GP214: PT/OL(0.5')/GM	-	stable	-	L	mostly gravel	defined channel - dry (Sept)	no	L
MP 154	kSFT26	South Fork Kuskokwim River tributary 26	Kuskokwim	none	outwash, silty gravel	stable	-	L	mostly gravel	no defined channel - dry (Sept)	no	L
MP 154	kSFT27	South Fork Kuskokwim River tributary 27	Kuskokwim	none	outwash, silty gravel	stable	-	L	mostly gravel	no defined channel - dry (Sept)	no	L
MP 157	kSHT15	Sheep Creek tributary 15	Kuskokwim	GP218: PT/OL (3.5')/SC		stable	-	M-H	thick frozen organic silt	defined channel - dry (Sept)	no	L, but potential downstream effects in breakup
MP 158	kSHT16	Sheep Creek tributary 16	Kuskokwim	none	colluvium/ alluvium: sand-silt over gravel	stable	-	L	minor silt potential	no defined channel - dry (Sept)	no	L

Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 158	kSHT17	Sheep Creek tributary 17	Kuskokwim	GP219: PT/OL (1')/GM-GP	-	stable	-	L-M	thin-moderately thin silt	no defined channel - dry (Sept)	no	L
MP 159	kSHT18	Sheep Creek tributary 18	Kuskokwim	GP219: PT/OL (1')/GM-GP, GP220: PT/OL (0.3')/SM/PT/SP-SM	-	stable	slight/slight	L	thin silt	defined channel - dry (Sept)	no	L
MP 159	kSHT19	Sheep Creek tributary 19	Kuskokwim	GP220: PT/OL (0.3')/SM/PT/SP-SM	-	stable	slight/slight	L	minor silt	no fish found, defined channel, winter dry	yes	L-M
MP 160	kSHT20	Sheep Creek tributary 20	Kuskokwim	none	colluvium/alluvium: gravel with silt to silty gravel	stable	-	L	mostly gravel	no defined channel - dry (Sept)	no	L
MP 160	kSHT21	Sheep Creek tributary 21	Kuskokwim	none	colluvium/alluvium: gravel with silt to silty gravel	stable	-	L	mostly gravel	no defined channel - dry (Sept)	no	L
MP 161	kSHT6	Sheep Creek tributary 6	Kuskokwim	none	till/outwash: silty/clayey sand with gravel to silty gravel	unstable	none/none	L	mostly sand-gravel	no defined channel - dry (Sept)	no	L
MP 162	kSHT22	Sheep Creek tributary 22	Kuskokwim	GP222: PT/GM/SC	-	unstable	slight/slight	L	mostly gravel-sand	no defined channel - dry (Sept)	no	L
MP 163	kSHT4	Sheep Creek tributary 4	Kuskokwim	GP224: PT/ML(1')/OL(2.5')/Ice+ML	-	unstable	none/none	H	frozen silt over ice	no defined channel - dry (Sept)	no	L, but potential downstream effects in breakup
MP 164	kSHT5	Sheep Creek tributary 5	Kuskokwim	GP224: PT/ML(1')/OL(2.5')/Ice+ML	-	unstable	-	H	frozen silt over ice	no fish found, defined channel, winter dry	yes	L-M
MP 166	DR94	Pitka Fork tributary, drainage 94	Kuskokwim	GP226: PT to 5'/SM	-	unstable	-	L	peat: high thaw settlement, but low erosion potential	too limited habitat for fish	yes	L
MP 166	KPI1	Pitka Fork	Kuskokwim	GP226: PT to 5'/SM	-	unstable	slight/slight	L	peat: high thaw settlement, but low erosion potential	no fish found, defined channel, winter dry	yes	L-M
MP 168	KWI1	Windy Fork	Kuskokwim	GP228: PT to 9'/OH	-	unstable (East bank only)	slight/slight	L-M	peat: high thaw settlement, but low erosion potential	coho salmon, Dolly Varden, slimy sculpin	yes	H
MP 170	kKHT1	Khuchaynik Creek tributary 1	Kuskokwim	GP231: PT/OL (0.5')/GM/SM	-	stable	none/none	L	thin silt, mostly gravel	no defined channel - dry (Sept)	yes	L
MP 173	kMFT1	Middle Fork Kuskokwim River tributary 1	Kuskokwim	GP235: PT/OL(3')/GP-GM	-	stable (West bank only)	none/none	M-H	thick organic silt	no defined channel - dry (Sept)	no	L, but potential downstream effects in breakup
MP 173	kMFT13	Middle Fork Kuskokwim River tributary 3	Kuskokwim	GP235: PT/OL(3')/GP-GM	-	stable	none/none	M-H	thick organic silt	no defined channel - dry (Sept)	no	L, but potential downstream effects in breakup

Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 176	KMFT16	Middle Fork Kuskokwim River tributary 16	Kuskokwim	GP238 East bank: PT to 7'/CL; GP239: unfrozen Pt/OL (1.8')/ML(2.5') on West bank	-	unstable (East bank only)	none/none	M	frozen peat and unfrozen silt	no fish found, defined channel, winter dry	yes	L-M
MP 176	KMFT17	Middle Fork Kuskokwim River tributary 17	Kuskokwim	GP239 just East of permafrost extent: unfrozen Pt/OL (1.8')/ML(2.5')	moraine: Sand/Silt w/ Gravel to Silty Gravel	stable	-	L-M	minor-moderate silt	no defined channel - dry (Sept)	no	L
MP 178	kMFT9	Middle Fork Kuskokwim River tributary 9	Kuskokwim	GP241: PT/ML(3')/SM	-	stable (West bank only)	slight/slight	H	thick frozen silt	low, discontinuous surface flow	yes	L, but potential downstream effects in breakup
MP 179	kMFT5	Middle Fork Kuskokwim River tributary 5	Kuskokwim	GP244: PT/ML (3')/CL and GP243: PT/CL (3')/GM	-	stable (West bank only)	none/none	H	thick frozen silt over clay W bank	Dolly Varden	yes	H
MP 179	kMFT19	Middle Fork Kuskokwim River tributary 19	Kuskokwim	GP244: PT/ML (3')/CL and GP243: PT/CL (3')/GM	-	stable (West bank only)	none/none	H	thick frozen silt over clay W bank	Dolly Varden	yes	H
MP 180	kMFT6	Middle Fork Kuskokwim River tributary 6	Kuskokwim	none	outwash: ice-rich clay with gravel to sandy gravel	unstable	slight/slight	M		Dolly Varden	yes	H
MP 181	kMFT20	Middle Fork Kuskokwim River tributary 20	Kuskokwim	none	outwash: sand/silt with gravel to silty gravel	unstable	-	L-M	minor-moderate silt	no fish found, defined channel, winter dry	yes	L-M
MP 181	kMFT7	Middle Fork Kuskokwim River tributary 7	Kuskokwim	GP245: PT/OL (unfrozen 0.3')/ML (1.5' unfrozen)/frozen SM	-	stable	none/none	L-M	moderately thick silt, but unfrozen	no fish found, defined channel, winter dry	yes	L-M
MP 183	kMF1	Middle Fork Kuskokwim	Kuskokwim	GP247: unfrozen GP-GM; GP248: PT/frozen OL(0.5')/frozen ML (1.5')/GP-GM	-	unstable (West bank only)	-	M-H	GP248 upper W bank high erosion potential; GP247 lower W bank low erosion potential	Dolly Varden, slimy sculpin, Coho salmon	yes	H
MP 184	kMFT10	Middle Fork Kuskokwim River tributary 10	Kuskokwim	GP250: PT/OL(0.5')/ML (9')	-	unstable	active/active	H	thick frozen silt	Dolly Varden, slimy sculpin	yes	H
MP 186	kMFT11	Middle Fork Kuskokwim River tributary 11	Kuskokwim	none	moraine: sand/silt with gravel to silty gravel	unstable	-	L-M	minor-moderate silt	no defined channel - dry (Sept)	no	L
MP 186	kBIT9	Big River tributary 9	Kuskokwim	GP254: PT/ML (1')/PT to 5'/SM	-	unstable	-	L-M	minor-moderate silt	no fish found, defined channel, winter dry	no	L-M
MP 187	kBIT12	Big River tributary 12	Kuskokwim	GP255: PT/OL(0.3')/CL to 5'/ML and GP256: PT/unfrozen ML (3')/SC	-	unstable	none/none	M-H	thick frozen CL E bank; unfrozen thick ML W bank	no fish found, defined channel, winter dry	yes	L-M

Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 188	kBIT14	Big River tributary 14	Kuskokwim	None	kettle & kame/moraine: sand/silt with gravel to silty gravel, ice-rich	unstable	-	M	minor-moderate silt	no defined channel - wetland	yes	L
MP 193	kBIT4	Big River tributary 4	Kuskokwim	GP262: PT/unfrozen CL to 3.5'/frozen CL	-	unstable (West bank only)		M-H	thick frozen clay, W bank upper slope	no fish found, defined channel, winter dry	yes	L-M
MP 195	kBIT99	Big River tributary 99	Kuskokwim	GP264: PT/unfrozen OL/unfrozen CL to 4'/frozen CL	-	unstable	-	L-M	minor-moderate frozen clay to trench depth	no fish found, defined channel, winter dry	yes	L-M
MP 195	kBIT6	Big River tributary 6	Kuskokwim	GP264: PT/unfrozen OL/unfrozen CL to 4'/frozen CL to 8.5'	-	unstable	-	L-M	minor-moderate frozen clay to trench depth	no fish found, defined channel, winter dry	yes	L-M
MP 203	kBIT8	Big River tributary 8	Kuskokwim	GP274: PT/unfrozen ML to 4.5'/frozen ML	-	unstable	none/none	M	thick silt, but mostly unfrozen	no fish found, defined channel, winter dry	yes	L-M
MP 206	kTLT3	Tatlawiksuk River tributary 3	Kuskokwim	GP279 in unstable permafrost to West: PT/CL(3.5')/ML (1')	till/colluvium: sand/silt trace gravel	stable	none/none	M	minor-moderate silt in surficial unit; thick frozen clay in boring to West	no fish found, defined channel, winter dry	yes	L-M
MP 207	DR86	Tatlawiksuk River tributary, drainage 86	Kuskokwim	GP279: PT/CL(3.5')/ML (1' to 5' depth)	-	stable	-	M-H	thick frozen clay	too limited habitat for fish	yes	L, but potential downstream effects in breakup
MP 207	kTLT4	Tatlawiksuk River tributary 4	Kuskokwim	GP279: PT/CL(3.5')/ML (1')	-	stable	none/none	M-H	thick frozen clay	no fish found, defined channel, winter dry	yes	L-M
MP 208	kTLT5	Tatlawiksuk River tributary 5	Kuskokwim	GP280: PT/unfrozen OL (0.5')/frozen CL-ML(2.5')/GP-GM	-	stable	slight/slight	M-H	thick frozen clay-silt	Dolly Varden	yes	H
MP 208	kTLT99	Tatlawiksuk River tributary 99	Kuskokwim	GP280: PT/unfrozen OL (0.5')/frozen CL-ML(2.5')/GP-GM	-	stable	-	M-H	thick frozen clay-silt	no fish found, defined channel, winter dry	yes	L-M
MP 213	kTLT36	Tatlawiksuk River tributary 36	Kuskokwim	GP287: PT/ frozen OL (0.5')/unfrozen ML(3.5')/frozen SM	-	stable (West bank only)	-	M	thick silt, but mostly unfrozen	no fish found	yes	L-M
MP 214	kTLT9	Tatlawiksuk River tributary 9	Kuskokwim	West bank no permafrost; East bank in stable permafrost GP287: PT/ frozen OL (0.5')/unfrozen ML(3.5')/frozen SM	bog silt and peat (>2') over till (sandy silt with trace gravel)	stable	none/none	M	thick silt, but mostly unfrozen	coho and Chinook salmon	yes	H
MP 283	KEF2	East Fork George River	Kuskokwim	EG-3/EG-4: PT+unfrozen ML(0.3')/unfrozen SM/frozen SP-SM	-	stable (West bank only)	slight/active	L	HDD site to be setback from bank, low erosion potential near surface	coho, Chum, and Chinook salmon; Arctic grayling, Burbot, Dolly Varden, whitefish, slimy sculpin, ninespine stickleback	yes	H

Table 3.2-9: Stream Crossings in Permafrost Terrain – Screening for Erosion Vulnerability

Nearest Milepost	Stream Crossing			Soil Type	Permafrost Information					Fish Information		
	Stream ID	Stream Name	Drainage	Borehole Data to 5' (silt thickness in feet) (1)	Terrain Unit (if no borehole data)	Thaw Settlement (2)	Existing Bank Erosion (Left Bank/Right Bank) (3)	Level of Permafrost Bank Erosion Concern (4)	Rationale for Permafrost/Soil Erosion Rating	Fish Presence or Potential (5)	Water Present in Late Summer for Baseline Sampling	Level of Fish Concern (6)
MP 283	KEF12	East Fork George River tributary 12	Kuskokwim	GP-342: PT(0.2')/CL	-	stable	-	M-H	E. George HDD setback also avoids this crossing	not sampled	-	-
MP 284	KEF13	East Fork George River tributary 13	Kuskokwim	GP-342: PT(0.2')/CL	-	stable	-	M-H	E. George HDD setback also avoids this crossing	not sampled	no	-
MP 241	kGE2	George River	Kuskokwim	G-4: PT+ML(0.4')/SM(2.1')/ML	-	Stable (West bank only)	slight/ -	H	HDD site to be setback from bank, low erosion potential near surface	coho, Chum, and Chinook salmon; Dolly Varden, whitefish, slimy sculpin	yes	H

- Notes:
- From CH2MHill (2011) and BGC (2013): CL=clay, GM=silty gravel, GP=gravel, ML=inorganic silt, OL=organic silt, PT=peat, SC=clayey sand, SM=silty sand, SP=poorly graded sand, SW = well-graded sand.
 - Stable if <1' settlement when thawed to 25', unstable if >1' settlement when thawed to 25', based on thaw modeling by Fueg (2014).
 - From OtterTail (2013).
 - Rationale for permafrost erosion concern:
High: thick (>1') inorganic silt
Moderate-High: thick organic silt or clay (may bind better)
Low-Moderate: silt =1' or peat >5' over fines (assumes all peat would be trenched/removed), fines on trench bottom only
Low: <1' silt; dominantly gravel or sand; peat >5' over coarse material (peat=high settlement but low erosion potential)
 - From OtterTail (2012a) Fish Map book or SRK (2013b)
 - Rationale for fish concern:
High (H): fish found (any kind)
Low-Moderate (L-M): defined channel/habitat/water present in late summer, but no fish found; could be some though; channel dry in winter
Low (L): no defined channel, limited habitat, wetlands, dry in fall, low discontinuous flow
 - = not available or not applicable

Results:
~400+ stream crossings
~80 in permafrost terrain
~30 in permafrost terrain + erodible soils (Moderate to Moderate-High overall ratings, blue or oranges)
~20 in permafrost terrain + erodible soils + fish habitat (Moderate-High overall ratings, oranges)
8 in permafrost terrain + erodible soils + fish habitat + fish found (Moderate-High overall rating, bright orange): Jones Creek tributary #10, Middle Fork Kuskokwim River + 4 tributaries, 2 Tatlawiksuk River tributaries

Sources: CH2MHill 2011b; OtterTail 2012a; BGC 2013c; SRK 2013b; Fueg 2014.

Combined permafrost erosion and fish concern:	
Moderate-High:	Stream crossings with high to moderate permafrost erosion concern with fish present.
Moderate-High:	Stream crossings with a) high or moderate-high permafrost erosion concern in absence of fish, if potential fish habitat identified; or b) high permafrost erosion concern in absence of fish habitat due to potential effects on wetlands or downstream effects on larger fish stream in breakup.
Moderate	Stream crossings with a) moderate-high permafrost erosion concern in absence of fish habitat, dry in late summer, and rated moderate overall due to potential downstream effects on larger fish stream in breakup; and b) low-moderate permafrost erosion concern with fish habitat present.
Low	Stream crossings with a) low permafrost erosion concern regardless of fish habitat or presence; b) low-moderate or moderate permafrost erosion concern with no fish or habitat present, dry in late summer; or c) unstable permafrost and fish present, but horizontal directional drilling (HDD) planned for crossing.

3.2.2.3.4 SOIL QUALITY/CONTAMINATED SITES

Review of the federal CWA Impaired Water Section 303(d) listings indicated that no known affected watersheds are present along the proposed pipeline corridor. Review of the federal CERCLIS database indicated no known federally funded Superfund sites within the proposed pipeline corridor.

Review of the ADEC Contaminated Sites database indicated no sites within the proposed pipeline corridor of Alternative 2; however, about six sites are located near the proposed Beluga camp and storage yard, and a number of additional sites are located along the Alternative 3B proposed diesel pipeline corridor. In addition, several sites are located within communities near the pipeline corridor and may coincide with use of proposed infrastructure such as airfields. These sites are shown on Figure 3.2-9 and listed in Table 3.2-10 from south to north, and east to west.

Table 3.2-10: Contaminated Sites along Pipeline Corridor

ADEC Hazard ID	Site Name	Distance and Direction from Pipeline ROW or Infrastructure	Status
Tyonek/Beluga			
3030	VECO Three-Mile Creek Camp	2,900' SE	CC
2798	Tyonek North Forelands Facility	1,300' SE	O/CC
23511	Three-Mile Creek Services	3000' SE	CC
1845	West Cook Inlet Construction Yard	2,200' SE	CC
1000	Beluga River Abandoned Diesel Tank Farm	2,100' SE	O
1001	Beluga River Field	1,100' SE	CC
999	Beluga River 232-4'	1,200' SE	O
1273	Beluga River North Main Road Diesel	1,000' SE	CC
1284	Beluga River 214-35	2,100' SE	CC
991	Beluga River Tank Farm	1,300' SE	O
995	Beluga River 212-35	2,100' SE	O
990	Beluga River Pump Area Assessment	1,200' SE	O
2797	Marco Kaloa Property	2,100' SE	CC
1002	Beluga River 241-34	200' SE	CC
998	Beluga River Enstar Metering Facility	500' E	CC
25708	Chugach Electric Beluga Power Plant Transformer TRF183	500' W	C-IC
993	Beluga River CEA Meter Site Release	500' W	CC-IC
1282	Beluga River Fuel Line Removal	650' W	CC
667	Chugach Electric Power Plant Floor Drain	500' W	CC
996	Beluga River 224-23/232-26	800 SE	CC
994	Beluga River 212-24	1,650' SE	C-IC
987	Beluga River 221-23	2,000' NW	CC

Table 3.2-10: Contaminated Sites along Pipeline Corridor

ADEC Hazard ID	Site Name	Distance and Direction from Pipeline ROW or Infrastructure	Status
Rainy Pass			
1811	FAA Puntilla Lake Station	1,000' SW	O
Farewell			
1873	FAA Farewell Station	13,000' NW	O

Notes:

Includes sites within about ¼ mile of pipeline ROW and infrastructure (Figure 3.2-9).

Abbreviations:

ADOT&PF = Alaska Department of Transportation & Public Facilities

ADEC = Alaska Department of Environmental Conservation

FAA = Federal Aviation Administration

Source: ADEC 2013a.

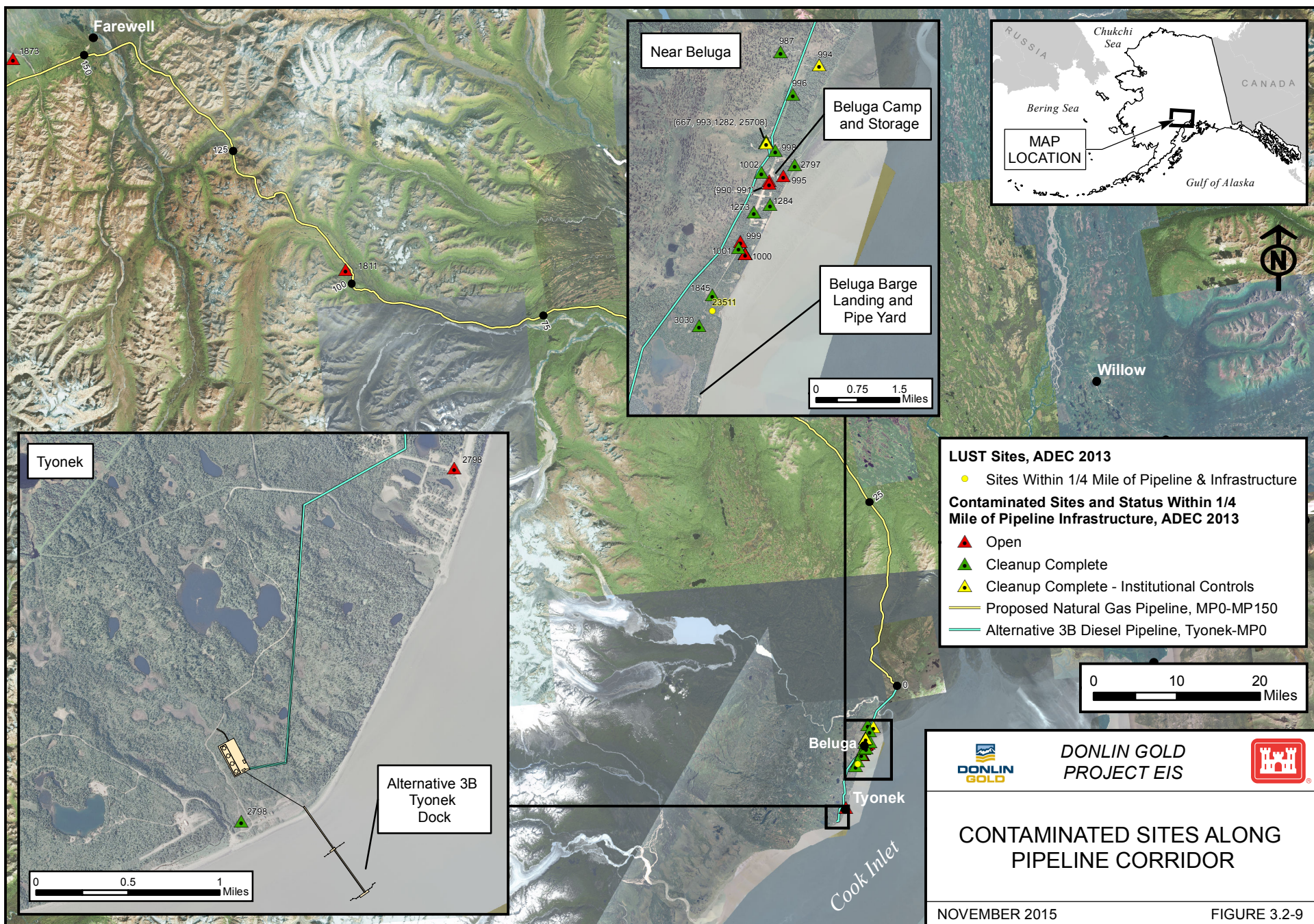
A number of contaminated sites were identified in the Tyonek/Beluga area associated with oil and gas field infrastructure and the Beluga power plant. Several of these are located within several hundred feet of the diesel pipeline alternative, and six surround the proposed camp and storage yard at Beluga, two of which are listed as open sites (Figure 3.2-9). These six include a private property, metering facility, tank farm, and other infrastructure associated with the Beluga River Gas Field. A group of four sites, listed as cleanup complete with institutional controls, are located about 500 feet northwest or upgradient of the diesel pipeline alternative; these include a floor drain, transformer, meter release, and fuel line removal associated with either the Beluga power plant or the Beluga River Gas Field. The rest of the sites are located on the downgradient side of the diesel pipeline alternative, south of the proposed camp and storage yard.

The FAA Puntilla Lake Station contains elevated levels of Diesel Range Organics in soils at the former location of three ASTs and associated piping. The tanks and pipelines were removed in 1999; however, no contaminated soils were removed during this effort and the site currently remains in an open status.

The FAA Farewell Station site represents a group of petroleum hydrocarbon impacts originating from heating oil tanks and piping associated with housing and other support buildings at the airfield. This site currently remains open in regard to cleanup status. The site is located approximately 3 miles northeast of the proposed pipeline route, and while it does not pose a major threat to the ROW, the airfield is proposed for use during pipeline construction and operations.

3.2.2.4 CLIMATE CHANGE

Climate change is affecting resources in the EIS Analysis area and trends associated with climate change are projected to continue into the future. Section 3.26.3 discusses climate change trends and impacts to key resources in the physical environment including atmosphere, water resources, and permafrost. Current and future effects to soils are particularly tied to changes in permafrost and increased risk of erosion (discussed in Sections 3.26.3.3 and 3.26.3.2).



3.2.3 ENVIRONMENTAL CONSEQUENCES

The levels of effects discussed throughout the analysis of soil impacts are related to criteria described in Table 3.2-11 below.

Table 3.2-11: Impact Criteria for Effects on Soils and Permafrost

Type of Effect	Impact Component	Effects Summary		
Changes to Soils or Permafrost	Magnitude or Intensity	Low: Changes in soils may not be measurable or noticeable. Thermal regime is maintained and rehabilitation can be accomplished through natural recolonization. Standard BMPs are successful in preventing erosion. Soil quality effects are below regulatory limits, or within range of natural baseline variation outside of mineralized zone.	Medium: Disturbance requires revegetation by active methods (such as seeding or sod replacement) to prevent drainage/erosion issues and for successful site rehabilitation. Design is adequate for expected range of permafrost hazards. Special BMPs and more frequent monitoring/maintenance needed for successful erosion control. Soil quality effects are small compared to baseline; and/or can be mitigated to stay within baseline ranges or below levels of human health concern.	High: Acute or obvious changes in resource character. Permafrost disturbance results in settlement requiring substantial fill for successful rehabilitation to prevent ponding or erosion. Active methods required for revegetation. BMPs are unsuccessful in controlling erosion. Permafrost hazards likely to exceed design parameters. Soil quality substantially exceeds baseline; mitigation not effective.
	Duration	Temporary: Soils or permafrost would be impacted not longer than the span of the project construction and would be expected to return to pre-activity levels at the completion of the activity.	Long-term: Soils or permafrost would be impacted through the life of the project and would return to pre-activity levels up to 100 years after completion of the project.	Permanent: Irreversible impact on soil character/quality or thermal regime. Resources would not be anticipated to return to previous levels. Rehabilitation not possible for many years after life of project.
	Geographic Extent	Local: Impacts to soils or permafrost limited geographically; discrete portions of the Project Area affected.	Regional: Affects soils or permafrost beyond local area, potentially throughout the proposed Project Area or outside the Project Area.	Extended: Affects soils or permafrost beyond the region or the EIS Analysis Area.
	Context	Common: Affects usual or ordinary resources widely distributed in region; not depleted or protected by legislation.	Important: Affects depleted resources within the locality or region, resources protected by legislation, or resource hazards governed by regulation.	Unique: Affects unique resources or resources protected by legislation.

Notes:
BMP = Best management practice

Impacts to soil can be substantially reduced or controlled through the proper application of BMPs, and specific plans like erosion and sedimentation control plans (ESCPs), and SWPPPs. In most cases, the necessary agency permits will specifically require such plans to be completed, reviewed, and approved before work can commence. Appendix F describes planning

documents, instituted programs, and associated permitting requirements that either comprehensively or partially address soil impacts through design features and BMPs. These are considered part of the proposed project and are assumed to be in place in the analysis of effects in this section.

The evaluation of permafrost hazard impacts on the Project and the environment incorporates an understanding of planned mitigation in the form of engineering design and maintenance that can greatly reduce impacts. Where known based on Donlin Gold plan documents and engineering reports, planned mitigation (e.g., design to withstand permafrost effects) are considered part of the Project description, and ratings criteria are applied with them included. This is also the case where such planned mitigation may not be specified, but is considered typical or standard engineering practice. In cases where planned mitigation is unknown or unclear, and may not be a common situation encountered, the lack of planned mitigation is taken into account in the impact ratings, and mitigation recommendations are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation, that could reduce impact levels.

The following sections detail the impacts of the various alternatives on soil resources, as well as the potential impacts of soil hazards on the alternatives. Effects evaluated include those related to soil disturbance, permafrost degradation, erosion, and soil quality issues (fugitive dust and contaminated sites). In evaluating negative and positive impacts on soils, relevant factors for this project include:

- The types and area of soil that would be disturbed, and whether project footprints would be reclaimed;
- The amount of permafrost degradation expected, as well as permafrost hazard effects on project infrastructure;
- Net erosion expected in the presence of planned BMPs;
- The presence of pre-existing contaminated soils that could affect project activities; and
- Planned project activities that could have an effect on soil quality (unplanned situations that could affect soil quality are covered under Section 3.24, Spill Risk).

3.2.3.1 ALTERNATIVE 1 – NO ACTION

The No Action Alternative is representative of existing conditions. Development, operation, and reclamation (close out) activities associated with the mine site area, transportation facilities, natural gas pipeline, and other proposed alternatives would not exist. For these reasons, no project-related impacts to soil conditions would exist under this alternative.

3.2.3.2 ALTERNATIVE 2 – DONLIN GOLD'S PROPOSED ACTION

3.2.3.2.1 SOIL DISTURBANCE/REMOVAL

Soil impacts addressed in this section are primarily concerned with the types and amounts of soils disturbed by the project. Per NRCS, soil depth thickness descriptors include very shallow (i.e.,-surface) soils (< 20 inches); shallow soils (10 to 20 inches); moderately deep (20 to 40 inches), deep soils (40 to 60 inches), and very deep soils (> 60 inches). Soil depths generally most susceptible to disturbance throughout the Project Area are the productive, organic rich

materials in surface to moderately deep soils; however, this can extend to greater depths. These soils are collectively referred to as surface soils. Although overburden is inclusive of soils, soils and select overburden will be managed based on growth media attributes and end use applications. Disturbances of bedrock and surficial geologic deposits (overburden beneath surface soils), including effects at material sites, are addressed in Section 3.1, Geology. Permafrost degradation and soil erosion are addressed separately in Sections 3.2.3.2.2 and 3.2.3.2.4, respectively. Impacts to vegetation, invasive species prevention and associated management practices are addressed in Section 3.10, Vegetation. Impacts to wetlands as a result of reduction/loss of soil productivity through dewatering, disturbance/removal are addressed in Section 3.11, Wetlands. Emission of greenhouse gases derived from soil induced processes (wetlands and permafrost) is addressed in more detail in Section 3.8, Air Quality.

Mine Site

Construction

The total estimated footprint of potential disturbances to soils at the mine site area during construction phase of the project (pre-production) would be roughly 5,800 acres, including: 80 acres at the open pit, 2,400 acres at the Tailings Storage Facility (TSF), about 700 acres in the first few lifts of the Waste Rock Facility (WRF), and roughly 2,600 acres for other mine site infrastructure (BGC 2011b; SRK 2012a, c, f). The geographic extent of soil disturbances at the mine site is considered local, as they would be contained within discrete footprints within the overall Project Area.

Soil disturbances of specific mine site components would directly result in medium to high intensity effects over the 3- to 4-year construction period from noticeable to obvious changes in soil cover, ranging from compaction to complete removal of surface soils and permanent placement of engineered fill, stockpiles, or waste materials over existing surfaces. Selective reclamation of disturbed areas would be implemented immediately (concurrent) with the construction phase as practicable. Major mine components and related surface soil changes and design features utilized to minimize effects include the following:

- *Pit Preparation and Related Stockpile Materials:* Surface soils and overburden excavated from the open pit would be stockpiled and salvaged for concurrent and future reclamation activities, and placed in two specially designed stockpiles designated as the north overburden stockpile (NOB) and south overburden stockpile (SOB). The NOB would receive materials such as woody debris, peat, loess, and alluvium, which would be used as growth media to revegetate reclaimed areas at closure. These materials would come from topsoil and subsoil layers, which contribute to soil productivity with organic matter, nutrients, and minerals (O, A, and B horizons); as well as fine-grained parent material (C horizon) which have physical properties that affect soil productivity like drainage and porosity. NOB materials would have a minimum 50 percent composition of fine-grained materials, of which 50 percent would ideally consist of organics. These materials would be segregated from coarser, less productive parent material (such as colluvium and terrace gravels) which would be placed in the SOB (SRK 2012a). The stockpiles would remain uncovered throughout operations. Moisture content, drainage, and erosion would be managed through berms and diversion channels as further described below and in Section 3.2.3.2.3.

- *NOB and SOB Stockpile Design:* The fine-grained peat/loess mixtures in the NOB stockpile would be used to reclaim the WRF and are anticipated to have low strength and high moisture/ice characteristics. The NOB stockpile would include a containment berm constructed of locally derived, coarse-grained, ice-poor, colluvium and alluvium materials. The stability of the containment berm would not rely on any strength characteristics of impounded fine-grained materials. The NOB stockpile will be constructed in three lifts totaling approximately 198 feet in height. The SOB stockpile would generally receive structurally competent, ice-poor, coarse-grained overburden materials derived from the American Creek area. The proposed stockpile design (overlapping lifts) would rely on the structural characteristics of the stockpiled materials, which would not exceed a 20 percent organics/fine-grained soil concentration by volume for compaction. The SOB will be placed in five lifts totaling approximately 165 feet in height.
- *TSF and Related Stockpiles:* Major components of the proposed TSF include temporary and permanent dams and a lined tailings impoundment area to be constructed over a 2-year period. Prior to liner placement, surface soils up to 3 feet thick would be grubbed and stripped, and overburden up to 26 feet thick would be cleared to bedrock. To the extent practicable, excavated organics would be segregated for use as eventual TSF closure cover material. Impoundment clearing is intended to remove a majority of ice-rich materials that would contribute to differential thaw settlement (Section 3.2.3.2.2). Excavated shallow materials would be replaced with liner bedding material consisting of terrace gravel or comparable silty gravel mixture derived from terrace gravel source areas located along the east side of Crooked Creek and the mine pit (Section 3.1, Geology). Excavated overburden from the TSF would be placed into three separate engineered stockpiles downstream of the TSF, two of which would coincide with material sites to minimize additional surface soil disturbances and exploit engineered surfaces prepared during terrace gravel removal.
- *WRF:* During the construction period, existing soils beneath the first few lifts along the toe of the WRF would be pre-stripped for foundation stability purposes, and rock drains would be placed on existing soil surfaces above these lifts. A foundation of non-acid generating (NAG) rock would be placed on top of existing soils at the potentially acid generating (PAG) management area to isolate PAG material from the ground beneath (BGC 2011b).
- *Other Mine Site Infrastructure:* Topsoil and organic materials removed from ground surfaces during construction of the mine site and process components (tailings dam, freshwater dam, mill site, crusher, maintenance shops, etc.) would be salvaged and selectively stockpiled as growth media for later use. All timber and woody debris unsuitable for sale will be salvaged and stockpiled for future reclamation use or incorporated as amendment in the growth media. Salvaged overburden stockpiles retained for future reclamation use would be stabilized as necessary to minimize erosion and maintain viability for future use. Additional details regarding reclamation practices are addressed in the erosion section under Mine Site (Section 3.2.3.2.4).

The types of surface soils and unconsolidated deposits that would be disturbed during mine construction are described in Sections 3.2.2.1.1 and 3.1 (Geology), respectively. Based on review of available NRCS data applicable to the mine site and surrounding area, the disturbed surface

soil types are considered common in context based on their local and regional distribution. Furthermore, no agricultural areas are present in the vicinity of the proposed mine, nor are any areas considered to be prime farmland, forest land, or rangeland (see Section 3.15, Lands). These usage considerations are largely attributed to mine site soil characteristics as well as physical climatic conditions.

Operations and Maintenance

Continued disturbances to soil would occur throughout mine site operation, which would have an active life of approximately 28 years. The intensity and context of effects on soils would be the same as described above for construction. The area of soils removed from the pit would expand to roughly 1,500 acres. The TSF would be constructed in six stages over the mine life, reaching a maximum of 2,400 acres. Ongoing development of the WRF would continue throughout operations based on planned bottom up development, reaching a maximum of 2,500 acres where existing soils would be permanently covered with successive lifts of waste rock.

Additional disturbances to soil at other mine site infrastructure would include those associated with pit dewatering throughout operation. Pit dewatering will lower the groundwater table, resulting in adverse impacts to some sensitive soil conditions (i.e., wetlands) that presently rely on un-perched shallow groundwater processes. Soils (wetlands) most susceptible to dewatering activities are primarily located at low elevations in mine site drainages, as discussed in Section 3.11, Wetlands. Wetland areas susceptible to dewatering could total approximately 2,711 acres (BGC 2015b). Approximately 550 acres of the total acreage would be located outside the mine footprint (Donlin Gold 2015e). Soil disturbances will also result in the release of greenhouse gas (GHG) emissions. Calculated mean total organic carbon concentrations in wetland and upland surface soils (0 to 10 centimeters) at the mine ranged from 26.2 percent to 24 percent, respectively (ARCADIS 2014). Detailed discussion of GHG emissions from soils and other sources influenced by project activities are presented in Section 3.8, Air Quality.

Excluding the 550 acres of impacted wetlands (dewatering) located outside the mine footprint, the total area of previously undisturbed or permanently covered soils during the mine life, including those described under Construction, would be on the order of 9,000 acres (SRK 2012f). This total acreage of soil disturbance would be of a lesser value at any given period throughout the mine life or closure period due to planned concurrent or phased reclamation.

Selective reclamation of disturbed areas within the WRF, material sites, access roads, and other areas no longer required for mining activity would be implemented concurrently throughout the operational period whenever possible. These activities (described below in Closure, Reclamation, and Monitoring) would optimize beneficial stabilization and restoration of disturbed soils and vegetation in some areas of the mine site during operations, instead of postponement to mine site closure.

Closure, Reclamation, and Monitoring

Reclamation activities would occur throughout operations and at closure as mine components reach their intended design life. It is estimated that approximately 14.7 million cubic yards (cy) of non-organic material (overburden/growth media) and 8.7 million cy of organics (peat/woody debris) would be salvaged and reused for reclamation purposes (SRK 2012f). Growth media salvage and stockpiling would be an on-going process as the pit and WRF are

developed. Common measures implemented to reclaim disturbed soil areas would include contouring, ripping to mitigate compaction effects, placement of growth media, and revegetation. Additional measures may be introduced pending innovations in reclamation techniques as they become available. Further details regarding reclamation practices are addressed in the erosion section under Mine Site (Section 3.2.3.2.4).

Major mine site components that would be reclaimed in place at closure, remaining in perpetuity beneath engineered soil covers designed to promote controlled runoff and reduce infiltration, include the WRF and TSF. Soil and overburden consisting of primarily fine-grained peat/loess mixtures stored in the NOB stockpile would be used to reclaim the WRF. Borrow sites would be reclaimed using salvaged surface materials from each site. In the event that any TSF overburden stockpile material remains following TSF closure, these materials would also be used for additional reclamation of terrace gravel borrow sites. Additional closure proceedings associated with the WRF and TSF are presented in Section 3.2.3.2.3 (Erosion).

Surface soils would not be replaced within the mine pit. Cut benches, slopes, and haul roads in the pit would be left to naturally revegetate on their own. Additional disturbances to existing soils during the closure and reclamation phase would occur during construction of the Crevice Creek spillway from the TSF. The water treatment plant (WTP) would be sited in an area of soils previously disturbed during construction and operations.

The amount of growth media available in stockpiles is expected to be more than adequate for reclamation needs. Generally, a minimum of 6 inches would be applied to reclaimed sites needing additional growth media to promote revegetation, although application thicknesses may vary by facility and existing surface conditions, with rocky areas potentially requiring a greater thickness than areas with fines (SRK 2012f). Assuming that 7,500 acres of the mine site would be reclaimed, the volume of available stockpiled overburden and organics would allow for application of up to 2 feet of growth media on average.

Continued operation and inspection of reclamation infrastructure and soil covers would be conducted for a large portion of the mine area (roughly 7,500 acres) well after mine operations cease. This would include monitoring of the open pit, WRF, TSF, WTP, and associated drainage networks (SRK 2012c).

Soil disturbance during closure would be minimal, since activities would primarily focus on proposed reclamation. Proposed reclamation of exposed ground surface areas with growth media for soil stabilization and revegetation are considered viable and consistent with the proposed post mine land use objectives (recreation and wildlife). The effects would be permanent, of medium intensity (in that effects from engineered surface cover and topsoil replacement would be noticeable), and cover a local extent, for this common geologic resource.

Summary of Mine Site Impacts

Direct impacts to soils from ground disturbances at the mine site during construction and operation of Alternative 2 would range from medium intensity (e.g. noticeable compaction or burial of existing soils requiring revegetation) to high intensity (complete removal), although the intensity of effects in most areas would be reduced to medium through reclamation. These activities would result in the permanent alteration of a total of roughly 9,000 acres of surface soil, an extent considered local as it would be limited to areas within the mine footprint. The

disturbed surface soil types are considered common in context based on their regional distribution.

Transportation Facilities

Construction

Soil disturbances during construction of specific transportation facilities components would result in noticeable to obvious changes in soil cover, which could range from compaction to removal of surface soils and placement of engineered fill or stockpiles over existing surfaces. Soil disturbance effects would be localized within the footprints of specific transportation facilities components. Complete construction of the Angyaruaq (Jungjuk) Port and mine access road would span a period of approximately 1.5 years; however, both would be operational in approximately 0.5 years. Similar to the mine site, construction of transportation facilities would result in wetland disturbances and subsequent GHG emissions which are detailed in Sections 3.11, Wetlands and 3.8, Air Quality, respectively. Effects on soils for specific transportation infrastructure components are described below.

Mine Access Road and Airport: The proposed 30-mile long road between the mine site and Angyaruaq (Jungjuk) Port, and 3-mile spur road between the mine access road and airport, would be constructed as 2-lane, 30-foot wide, and all-season gravel roads with restricted public access. The total estimated area of soil disturbance associated with the roads and airstrip is approximately 400 acres. Soil disturbance effects during road construction would be permanent, as the roads would remain in perpetuity to support post-closure activities. About half of the route would be constructed using conventional cut and fill techniques, and half with elevated fill embankments about 3 to 5 feet thick. Heavy equipment would be used for conventional cut and fill construction techniques; no excessively large cuts or fills would be required (Recon 2011a). Elevated fill sections would be employed where permafrost and snow accumulation issues exist (Section 3.2.3.2.2). Scrub materials would be tracked over, and cleared materials placed on the downslope side of the clearing limits in sloped areas. Reclamation and surface stabilization measures would be implemented during and after construction (Section 3.2.3.2.4). If winter ground conditions are unsuitable, an estimated 92,000 cy of material and geotextile would be imported for suitable substrate materials over the southernmost 4 miles of road from the port (Recon 2011a). Road design alignments would be based on the American Association of State Highway and Transportation Officials (AASHTO) standards, or as required to meet transport specifications. Soil map units that would be impacted along the access roads, airstrip, and Angyaruaq (Jungjuk) Port are shown on Figure 3.2-1 and listed in Table 3.2-3. More than 90 percent of disturbed areas from road construction activities would impact two soil types that are regionally prevalent among slopes and low mountains of the Kuskokwim Hills and extend well beyond the proposed alignment corridor (i.e., R30MTB and R30MTC and Table 3.2-3). Less prevalent soil types within the road construction corridor, but also regionally common, include those associated with permafrost, floodplains, and terraces (Table 3.2-3 and NCRS 2008).

- *Material Sites:* Disturbances of surface soil at material sites along the mine access road would encompass roughly 440 acres. These effects would be the same as those described in Section 3.1, Geology.
- *Angyaruaq (Jungjuk) Port:* The proposed Angyaruaq (Jungjuk) Port would occupy an area of 26 acres including a 5-acre overburden stockpile. The port area would be

stripped of surface soil and overburden, which would be stockpiled in an engineered storage area. Approximately 10,000 cy of dredged material derived from shoreline development (sheetpile infrastructure) would also be placed in the stockpile. The overburden stockpile would be situated adjacent to the northernmost and upslope extent of the constructed port site pad. Construction BMPs would include surface stabilization and installation of erosion and sedimentation control (ESC) measures along disturbed surfaces, including the overburden stockpile.

- *Kuskokwim River Corridor:* Soils along the Kuskokwim River could potentially be disturbed at certain critical sections where barges may need to be relayed during low water conditions. Disturbances from mooring activities and intermittent foot traffic causing potential soil compaction at relay points are expected to be of low intensity. Based on information presented in Section 3.5, Surface Water Hydrology, impacts on riverbank soils from barge-induced wake would not substantially impact Kuskokwim River bank erosion rates based on river tractive energy studies of barge traffic, wave height, and energy (BGC 2015m). Wave heights during upstream travel were estimated to be between 0.05 and 0.22 feet, and approximately 0.34 to 0.74 feet during downstream travel with increased barge speed. Furthermore, the primary cause of bank erosion along the lower Kuskokwim River is related to thermo-erosional niching associated with high water levels. Additional information for estimated project barge requirements are addressed in Section 2.3 (Chapter 2, Alternatives).
- *Bethel Cargo Terminal:* Disturbances to soils at the proposed 16-acre cargo terminal would include grading, contouring, cut and fill, and paving to accommodate storage yards, berths, buildings, roads, and other facility infrastructure. Effects on soils would be of medium intensity, in that there would be obvious surface changes, but these would occur mostly on previously disturbed soils in an existing industrial area. Shoreline development would include construction of an open cell sheetpile bulkhead spanning approximately 850 feet to prevent erosion of the river bank. Approximately 40,000 cy of sand and gravel fill and 1,600 cy of riprap would be placed behind and at the ends of the sheetpile, resulting in the creation of about 3 acres of new ground containing well-drained surface soils (Corps 2014a). These high intensity effects would be localized and beneficial, in that they would result in the permanent creation of new soils useful for community and industrial purposes. Well-drained sandy soils range from common to important in the region, as much of the Bethel area is covered by poorly drained permafrost soils with difficult foundation conditions.
- *Bethel Fuel Terminal:* An existing fuel terminal at the Bethel Port would be used to support project fueling needs, with three additional fuel storage tanks constructed within the existing facility. The site is already developed and equipped with tank pads, liners, and containment to accommodate the additional tanks. Due to the existing fuel farm infrastructure, additional disturbances to native soil conditions during construction would likely be very limited, if any.
- *Dutch Harbor Port Site:* Indirect effects from expansion and upgrades to an existing third-party Dutch Harbor facility may impact an estimated area of 4 to 6 acres of soils. Disturbances to soils would be necessary during construction; however, it is possible that construction would occur in previously disturbed areas re-appropriated for fuel storage. Overburden would be temporarily displaced to accommodate construction of

tank foundations, secondary containment, pipeline distribution, and access. Soils derived from volcanic deposits in the Dutch Harbor area are widespread in the Aleutians and Alaska Peninsula, are generally poor or unsuitable for agricultural purposes (USDA 1979), and thus considered common in context.

Operations and Maintenance

Little to no additional soil disturbance is anticipated at the transportation facilities sites following construction. Minor maintenance dredging activities at the Angyaruaq (Jungjuk) Port would involve annual placement of an additional 1,200 cy of river sediment in the designated waste soil disposal area on the upslope side of the port area (Fernandez 2014b). (Effects of dredging in the river are discussed in Section 3.5, Surface Water Hydrology.) Road maintenance could involve minor grading or placement of additional fill in areas needing repair. Placement of material within previously constructed road and stockpile footprints would cause low intensity incremental effects from compaction and grading.

Indirect effects of maintenance dredging at the Bethel Port would likely involve placement of similar volumes of river sediment at an in-river location (Section 3.5, Surface Water Hydrology). Maintenance dredging details for this port are not yet available, and would be determined through a Corps permit process if a permit were issued (Corps 2014a). Disposal of maintenance dredge material at an upland location is not anticipated as the Bethel area is tidally influenced and saline material disposal at an uplands site is unlikely to be permitted.

Closure, Reclamation, and Monitoring

Project related soil disturbances during closure would be limited to the Angyaruaq (Jungjuk) Port. The mine and airport access roads would remain indefinitely to support post-closure activities at the mine, and the Bethel and Dutch Harbor facilities would likely continue to operate under third-party ownership. Incremental effects on soil disturbance from long-term road maintenance would be the same as described above under Operations and Maintenance.

The Angyaruaq (Jungjuk) Port would be reclaimed following removal of all above-ground infrastructure from the site, including sheetpile infrastructure and associated fill. Surface soils would be restored and stabilized through grading, contouring, and revegetation. These activities would initially be of medium intensity during reclamation, but would be beneficial over time due to permanent replacement of disturbed soils, resulting in low intensity effects that may not be noticeable. Additional closure and reclamation activities and BMPs for the port site related to erosion are presented in Section 3.2.3.2.4.

Summary of Transportation Facilities Impacts

Impacts to soils from ground disturbances at the various transportation facilities components during construction and operation of Alternative 2 would range from low intensity (e.g., minor compaction, grading in previously disturbed port areas) to high intensity (e.g., complete removal of native soils at road cuts), although the intensity of effects in some areas would be reduced to low to medium through reclamation. Soil disturbances under Alternative 2 would result in the permanent alteration of a total of roughly 900 acres of surface soil, an extent considered local as it would be limited geographically to areas within the footprints of the individual infrastructure components. Soil types associated within disturbed areas are mostly common in context (i.e., prevalent beyond the impacted areas).

Natural Gas Pipeline

Construction

Soil disturbance considerations for the pipeline include soil types impacted and the area of disturbance associated with proposed pipeline components. Construction activities resulting in soil disturbances to wetlands and subsequent GHG emissions are detailed in Sections 3.11, Wetlands and 3.8, Air Quality, respectively.

The proposed 315-mile pipeline alignment traverses a variety of soil types, physical conditions, and landscape terrains. Surface soils along the pipeline are described in Section 3.2.2.3.1, Table 3.2-7 and Table 3.2-8, as well as Figure 3.2-6 and Figure 3.2-7 for the eastern and central portions of the pipeline, and Section 3.2.2.1.1, Table 3.2-1, and Figure 3.2-8 for the western portion of the pipeline. Unconsolidated deposits and physiographic terrain are described in Section 3.1, Geology. Soil types present along the alignment are regionally prevalent and considered common in context.

Direct impacts to soils during construction would include low to high intensity effects ranging from minor compaction of frozen native soils to clearing, grading, excavation, fill placement, and installation (and removal) of buried and above-ground infrastructure. The total acreage of potential surface soil disturbances associated with ROW and off-ROW infrastructure throughout the construction period is approximately 11,500 and 2,600 acres, respectively (SRK 2013b). The geographic extent of effects is considered local, as soil disturbances are limited to discrete areas within the ROW and off-ROW facility footprints.

The construction period would span 3 to 4 years, including ROW preparation and initial infrastructure build-out to construction rehabilitation and reclamation. Preliminary winter work that could affect soils before the first year of pipeline installation would include clearing and grading of the ROW and certain access roads; material site development; construction of storage yards, camp pads, and new airstrips; and existing airstrip upgrades. Recovery of most soil disturbances would not be temporary, and are expected to be long-term in duration, with reclamation and soil/vegetation recovery within the first few years following construction. Longer lasting permafrost effects are described in Section 3.2.3.2.2.

Although some construction methods are common to various pipeline components, unique construction methods exist for specific components. Factors influencing soil disturbances include construction methodology, soil and vegetation sensitivities, and physical conditions inherent to the location and time of construction (i.e., seasonal conditions, slope gradient, permafrost, etc.). Construction activities that would create soil disturbances are described below for the ROW corridor and ancillary facilities located mostly outside the ROW.

Pipeline ROW

The ROW area that would be cleared for construction is roughly 5,750 acres (150 feet wide), with up to an additional 5,750 acres available (up to 300 feet wide) for additional temporary space that may be needed in areas of challenging ground conditions (SRK 2013b). Together these total 11,500 acres. As shown on Figure 2.3-28, the ROW would consist of three major surface components: the trench centerline area, a trench spoils side, and a working side with makeup areas and travel lane. While soils would be completely removed from the trench area, soil disturbance effects on the working and spoils sides of the ROW would consist primarily of soil compaction in relatively flat regions. Areas with large cross-slopes subject to cut-and-fill

construction would have greater areas of total soil removal. The total length of ROW with cross-slopes requiring cut-and-fill construction (generally greater than 6 percent) would be about 262 miles.

Pipe installation would occur in 8 sections over a 2-year period. The estimated duration of total construction at any single point along the pipeline ROW would be approximately 3 to 4 months from initial surveying to finish grading. Approximately 68 percent, or 215 miles of the total pipeline length would be constructed during frozen winter conditions to minimize soil disturbances from support equipment. Approximately 100 miles of the total pipeline length would be constructed in the summer. Areas selected for summer or fall construction would be based on geotechnical, terrain, safety, and work length (pipeline) continuity considerations. Favorable geotechnical conditions would include stable permafrost that would result in minimal ground settlement (< 1 foot) over the life of the pipeline, and/or suitable near surface soils to support equipment (e.g., gravel floodplains). A majority of the mitigation and restoration activities would be performed concurrently during construction, and would be completed during the spring shoulder season and/or the summer after pipe installation. Specific ESC and restoration measures for various pipeline components are presented in Section 3.2.3.2.4, and those specific to permafrost terrain are discussed in Section 3.2.3.2.2.

The 150-foot construction ROW area would be cleared of brush, trees, roots and other large obstructions before grading. Snow/ice, gravel, and/or graded work pads would be installed after clearing and grading. With the exception of two above-ground crossings over active faults, the pipeline would be installed subsurface in an excavated trench or through horizontal directional drilling (HDD) (Section 3.3, Geohazards and Seismic Conditions). Installation depths (cover) would be a minimum of 2-1/2 feet in upland soil, 4 feet in drainages or ephemeral waterways, and up to 10 feet at stream crossings for scour protection (Section 3.5, Surface Water Hydrology). The process of lowering in or making tie-ins with loaded sidebooms would be one of the main activities resulting in disturbance to surface soils and vegetation. Each sideboom will consist of CAT 561 or 572 –class tracked equipment. Up to three sidebooms (and other equipment as needed) will operate simultaneously to configure, lower, place, and situate each pipe segment for tie-in. In comparison to other pipeline construction activities, this process will generally result in the most localized heavy equipment track movement adjacent to the trench.

Soft soil conditions incapable of supporting construction equipment would be covered with work pads constructed of swamp mats, corduroy timber, granular rock materials or snow and ice. Wide track high flotation equipment (i.e., excavators) would also minimize disturbances to more sensitive soil conditions along the proposed alignment. Organic soil would be segregated and stockpiled during trench excavation, and re-used as growth media surface completion material following pipeline installation and backfilling. Where possible, attempts would be made to use finer grained materials in the absence of organic soils for future revegetation efforts. Temporary impoundment of saturated organic soils may be required during ditch excavation in wetland areas. Backfilling would be initiated as soon as practicable following pipe installation to minimize additional efforts to remove accumulated snow, precipitation, or resulting disturbances.

Ancillary Facilities

The following infrastructure would be located mostly outside of the construction ROW corridor resulting in soil disturbance effects ranging from low intensity, such as compaction of native soils for winter road construction or drilling in previously disturbed soils, to medium and high

intensity, such as grading and cut excavations along access roads and airstrips. Together, the off-ROW infrastructure throughout the construction period affects approximately 2,600 acres. Specific ancillary facility descriptions are addressed in Section 2.3 (Chapter 2, Alternatives), and include corresponding footprint acreages, lengths (where applicable), and seasonal usage.

- *Temporary Roads:* These would include graded or gravel-filled access roads for all season use, and ice access roads that would be limited to winter activities only. Approximately 45 new temporary access roads and shoofly roads would be used in the summer only; 59 used in winter only; and 13 constructed for all season use (SRK 2013b). Temporary roads would include a seasonal winter access corridor (Oilwell Road or Willow Landing Route) that would serve as a major supply route from the Parks Highway (see Figure 2.3-23). The access corridor would be constructed mostly on existing winter trails. The winter access corridor would require minimal clearing, and would be on frozen ground conditions fortified with ice from water withdrawal sites. Equipment accessing the winter corridor would consist of tracked or rubber-tired vehicles with greater weight-to-surface area distribution to minimize compaction of soils underlying the snow and ice.
- *Camps and Storage Yards:* These temporary facilities include mainline construction camps, airstrip construction camps, smaller fly-in camps, HDD camps and worksites, and pipe and equipment storage yards comprising a total of about 300 acres. Impacts to surface soils would include mostly medium intensity disturbances during grading, leveling, and drilling activities. Storage yards would generally be developed approximately 1 year before the pipe-laying season, and would be cleared and graded with gravel if existing soil conditions are unsuitable. Camps would be relocated at the end of each construction season and demobilized as pipeline construction is completed.
- *Material Sites:* Approximately 70 potential materials borrow sites would impact a total estimated area of about 1,100 acres. The sites would supply gravel fill material for roads, airfields, camp pads, storage yards, compressor station, and gravel work pads (as needed). Sites would be situated in areas that avoid environmentally sensitive areas. Topsoil at these sites would be removed and stockpiled for later reuse during reclamation. Additional effects and mitigation measures at these sites in relation to surficial deposits and resource reduction are discussed in Section 3.1, Geology.
- *Airstrips:* A total of 12 new and existing airstrips would be used to support construction activities. No new earthwork would be required at three airstrips which include the Beluga Airstrip, Farewell Airstrip, and Donlin Gold Airstrip (mine site). While new airstrip locations have been selected to minimize cut and fill construction requirements, high intensity cut excavations, fill placement, and contouring would be required at six airstrips. Clearing and grading only (medium intensity soil disturbance) would be conducted at the three remaining airstrips. An area of approximately 673 acres would be disturbed through construction of new airstrips ranging in lengths of 3,500 feet to 5,000 feet. Specific airstrip details are addressed in Section 2.3 (Chapter 2, Alternatives).
- *Compressor Station and Transmission Line:* Construction of the compressor station would disturb approximately 2 acres of soils. The transmission line to the compressor station would disturb soils co-located within the first 0.4 miles of the pipeline ROW, and a 30-foot wide strip of previously disturbed ground along 8 miles of the existing Chugach Electric Association transmission line corridor to the Beluga Power Plant. The line would be buried from the metering station at MP 0 to the compressor station. An

estimated 134 poles spaced approximately every 325 feet would be required. Depending on soil conditions, poles would either be drilled to a depth of 10 feet, directly embedded, or H-pile driven.

- *Valves, Pig and Metering Stations:* Small areas of soil disturbance comprising less than 1 acre total are associated with three pig launcher and receiver stations, metering stations located at either end of the pipeline, and 19 main line (block) valves (MLVs). Two of the three pig stations and four of the 19 MLVs would be co-located with other planned structures (e.g., compressor station).

Operations and Maintenance

Since all temporary facilities, roads, airstrips, and storage yards would be reclaimed immediately following construction, soil disturbances attributed to pipeline operation are limited to facilities and footprint areas retained for use. No new or expanded infrastructure, such as airstrips or roads, is planned during pipeline operation. With the exception of the compressor station and other permanent ancillary needs, the construction ROW area would not be retained outside the permanent ROW. Area estimates for proposed pipeline operation activities include about 1,900 acres for the reduced, post-construction, pipeline ROW and about 30 acres for the proposed transmission line. O&M activities and inspections related to ESC are described in Section 3.2.3.2.4. Corrective maintenance activities that have the potential to disturb previously restored soil conditions include routine and non-routine pipeline monitoring and maintenance activities such as vegetation clearing, removal/replacement of equipment, pipeline inspections, and ROW mitigation and stabilization that could potentially occur anywhere along the length of the pipeline. Soil disturbance during these activities would be localized and involve low to medium intensity compaction, fill placement, or grading. The duration of effects could be temporary to long-term, occurring intermittently over the planned period of use (30 years), and potentially persisting for months or years beyond initial disturbance until stabilization criteria are met. These activities would be performed per the established O&M Plan/Manual, and follow BMPs and directives outlined in the Stabilization, Rehabilitation and Reclamation (SRR) Plan and ESCP (Section 3.2.3.2.3).

Closure, Reclamation, and Monitoring

A variety of future conditions may influence final closure determinations (continued use, retained infrastructure, etc.); however, discontinued use of the pipeline and associated infrastructure is assumed for planning purposes and analysis of soil effects. As described in Section 3.2.3.2.3, a revised SRR Plan would be developed at closure to address final reclamation actions, and incorporate BMPs and ESC/restoration measures based on review of prior practices.

In-place abandonment of all subgrade pipeline following purging would cause little to no surface soil disturbance along most of the ROW. All above-grade pipeline and structural facilities would be removed. Pipeline surface protrusions and foundation piles would be capped/blinded below ground surface. Gravel pads would be left in place, and salvaged overburden stockpiles distributed and spread. Surfaces would be scarified in preparation for revegetation. Soil disturbances would likely be more intensive where above-grade abandonment activities occur, such as at fault crossings, the compressor station, and pig launcher/receiver stations, where closure activities are anticipated to be of medium intensity

and include small excavations, grading, contouring, and revegetation. The duration of impacts during closure are expected to be similar to those for operations, ranging from temporary for the majority of the pipeline, to long-term where some disturbances persist beyond termination until stabilization criteria are met. While the season of final pipeline termination/reclamation is not specified in the current pipeline *Plan of Development* (SRK 2013b), closure activities that occur during the winter season (similar to construction) would help to minimize surface disturbances to soil (Chapter 5, Impact Avoidance, Minimization, and Mitigation).

Summary of Natural Gas Pipeline Impacts

Impacts to soils from ground disturbances along the pipeline ROW and ancillary facilities during construction, operation, and closure of Alternative 2 would range from low intensity (e.g., minor compaction of frozen native soils along winter roads) to high intensity (e.g., cuts and fills along ROW, roads, and airstrips), although the intensity of effects would be reduced to low to medium in most areas through reclamation following construction. Soil disturbances under Alternative 2 would impact a total of 8,350 to 14,100 acres, depending on the amount of additional ROW space needed in areas of challenging ground conditions; while the pipeline crosses several regions of Alaska, this extent of impacts is considered local as they would be limited to areas within the footprint of the construction ROW corridor and individual infrastructure components. Soils would be permanently altered in areas of high intensity construction effects, although the duration of most effects following reclamation would range from temporary to long-term where disturbances persist for several years until stabilization criteria are met. Soil types present along the alignment are regionally prevalent and considered common in context.

3.2.3.2.2 PERMAFROST

Mine Site

Construction

Permafrost stability or anticipated changes to existing permafrost conditions can substantially influence design and construction of the project. Sporadic discontinuous permafrost is present throughout the mine site area (Section 3.2.2.1.2 and Figure 3.2-2), is regionally extensive in Alaska, and is considered a common resource in context. Ice-rich soils at the mine site that are most susceptible to differential thaw settlement are generally associated with valley bottoms and lower slopes, thick organic cover, poor drainage conditions, and a relatively thin active layer.

The intensity of effects on permafrost in disturbed areas would range from low intensity, where thawing in areas of thaw stable soils does not result in noticeable ground settlement, to medium to high intensity, where complete or partial excavation of frozen, thaw unstable soils is required beneath major mine site components to achieve tolerable design limits and reduce the magnitude of effects.

Permafrost removal is a requirement for the project, given that existing permafrost could potentially result in adverse impacts on the stability of important structures if not mitigated. The extent of frozen soils that could potentially cause major consequences from structural failure is localized beneath the specific structures. Physical forces associated with these

structures concerning permafrost and structural integrity generally include, but are not limited to increased heat transfer and loading forces (e.g., overburden, hydrostatic, etc.).

Other effects associated with permafrost degradation include the release of GHGs when thawed. Estimates of permafrost GHG emissions resulting from mine site construction activities are presented Section 3.8, Air Quality. Effects on and from permafrost are described below for specific mine site facilities:

Effects on permafrost

- *Dams (TSF and Other):* Planned design features for all dams (temporary or permanent) would require complete excavation of overburden and ice-rich materials to bedrock followed by replacement with suitable fill material. The purpose of this is to increase the strength and stability of the dam foundation by locating it directly on bedrock. These actions are expected to reduce the likelihood and magnitude of impacts from permafrost hazards on dam stability to low likelihood and low intensity.

TSF Liner – Thaw Settlement: Ice-rich soils with greater than 20 percent visible ice in the form of segregated ice lenses have been observed at depths up to about 50 feet in the TSF valley bottom upstream of the dam, and up to 3 feet in midslope areas. These conditions are generally limited to silty soils where present. Frozen soils would be excavated within the impoundment area up to nominal depths of 3.3 feet in the valley bottom and 1.6 feet on the slopes to remove a majority of thaw sensitive organics and permafrost soils containing excess ground ice, but some permafrost would remain beneath the impoundment area. Progressive widespread thaw settlement is anticipated across the Anaconda Creek valley bottom over the operational period, and thawing of remaining permafrost foundation soils could result in differential settlement. This effect would be partially mitigated by pre-thawing during construction: liner bedding material sourced from gravel deposits would be placed on top of the stripped soils, compacted, allowed to thaw over one summer season, and recompacted prior to liner installation. Thaw settlement analyses based on a variety of conditions (i.e., moisture content, overburden pressures, etc.) were used to evaluate and select a relatively flexible, textured low density polyethylene (LLDPE) geomembrane liner (60 mil or 1.5 mm) that is expected to withstand freezing temperatures, sharp rocks, and anticipated settlement scenarios. Groundwater modeling studies of the TSF currently assume a small amount of leakage from liner defects (0.15 square inch flaw/acre, Section 3.6, Groundwater Hydrology). The proposed liner is unlikely to experience excessive strain from basin-wide settlement, and conditions that could result in excessive localized (abrupt) settlement that would challenge this defect assumption are also considered unlikely based on current understanding of bedrock conditions, overburden types, overburden thicknesses and distribution, ground ice distribution, and the planned over-excavation of shallow ice-rich soils (BGC 2011a). For example, using a maximum recommended allowable liner strain of 8 percent based on a factor of safety of 2 (below tested strain limits), BGC (2011a) predicts that a maximum differential settlement of 8 to 16 feet would have to occur over a short distance of 3 to 6 feet before the recommended limit is reached, and that such variable conditions are not expected to be present following impoundment preparation. If actual foundation conditions encountered during construction are more variable than anticipated, pre-thawing and recompaction during

construction are expected to mitigate the risk of differential settlement causing a compromised liner.

- *TSF Liner – Ice Loading:* The TSF liner could also be subjected to vertical and lateral stresses from ice on top of the TSF pond as a result of wind movement or water levels rising and falling, which could cause liner damage and increased seepage flow if not mitigated. It is expected that ice would not touch the liner if the tailings beach is developed and monitored successfully in the first few years of operations. In this case, no adverse effects are anticipated from ice loading. However, in the event that too much water accumulates in the pond before the tailings beach is established, Donlin Gold has proposed additional mitigation options to prevent damage to the liner. These include enhanced methods for tailings distribution and accumulation; geotextile tubes emplaced along perimeter benches and filled with tailings to stabilize beach development; floating buoys anchored to shore that could render the ice sheet immobile; or placement of a granular rock layer over the liner (BGC 2011a; BMT 2007).
- *WRF:* Ice-rich, fine-grained soil conditions exist in certain areas of the WRF which could create unstable conditions when thawed through development of excess porewater pressure. During construction, organic and ice-rich soils along the toe of the WRF beneath the first and third lifts would be stripped to secure the leading face of the WRF and reduce the likelihood of instability (SRK 2012e). The removed materials would be replaced with coarse, durable waste rock. Based on the proposed design and information presented in Section 3.3, Geohazards and Seismic Conditions, the WRF stability meets or exceeds design criteria under earthquake loading conditions, assuming that ice-rich soil and fine-grained material is removed from the toe of the WRF to an average depth of about 8 feet and that no remaining ice-rich materials would liquefy. However, if fine-grained and/or ice-rich soil conditions exist below this depth, the stability of the soils as they thaw under future loading conditions is uncertain with respect to seismic events (BGC 2011b) and could result in high intensity effects downgradient in the event of WRF deformation or slope failure. Recommendations for further investigation to determine if any additional liquefiable materials exist below this depth, and possible additional excavation during site preparation, are described in Chapter 5, Impact Avoidance, Minimization, and Mitigation. Additional seismic and earthquake information regarding WRF stability evaluation is presented in Section 3.3, Geohazards and Seismic Conditions.
- *Stockpiles:* Frozen soils and overburden from the open pit would progressively be stripped to bedrock, consolidated with selectively excavated ice-rich materials from the WRF and TSF, and placed in the NOB, SOB, and TSF overburden stockpiles. Each stockpile would be contained within a series of engineered berms for each independent lift of material to contain the high moisture content (ice), low strength materials, and would not rely on any cohesive strength attributes of the stockpiled materials. Partial excavation of ice-rich soil materials would be performed during construction of containment berms at the overburden stockpiles and ore body stockpile. For example, TSF overburden stockpile berms would be excavated to an average depth of 1.6 feet to remove unsuitable organic and ice-rich materials. Berms would be constructed of rock fill to facilitate subsurface drainage derived from the progressive thaw of stockpiled materials. Upstream berm faces would be lined with woven geo-fabric to entrain fine

material and minimize sediment infiltration into the berm rock fill material. These activities would likely result in irreversible impacts to permafrost during mine construction, but result in medium intensity beneficial effects on the stability of the berms and stockpiles, and their ability to contain sediment and protect downgradient water quality.

- *Plant Area Infrastructure:* Excavation and replacement of ice-rich shallow overburden materials with engineered fill may be necessary for specific mine site infrastructure, such as the fuel farm and containment area, process plant, and power plant slab foundations and structures, depending on the presence and severity of frozen soil conditions and site-specific design criteria. Foundation designs for plant area infrastructure are not specified in planning documents to date (SRK 2012a). While most of these facilities would be located on a shallow bedrock ridge with minimal permafrost, many data points are unconfirmed (Figure 3.2-2). Permafrost effects are likely to be of low intensity in this area, but would need to be confirmed in final design or site preparation. It is reasonable to assume that standard arctic construction BMPs, such as additional geotechnical evaluation, excavation of ice-rich permafrost, pile foundations, ground (thermal) insulation, or cooling (forced or natural convection), would be incorporated into these facilities in final design where appropriate and practicable to minimize heat transfer to frozen subsurface conditions.
- *Other Mine Site Areas:* As described in Section 3.2.3.2.1, insulative surface vegetation and soils would be disturbed or completely removed over a wide area at the mine site during construction for roads, storage yards, and laydown areas, and would be salvaged for future reclamation purposes. Roads involving conventional cut and fill construction methods would also disturb permafrost soils. The duration of interim removal (28 years) could result in appreciable permafrost degradation where present; however, elevated fill and unspecified final design plans and construction methodologies (BMPs) for infrastructure components would generally mitigate adverse settlement over respective service lifetimes.

Thus, the magnitude of effects from permafrost hazards in mine site construction are generally considered to be of low to medium intensity, and designs are expected to be adequate assuming that additional evaluation would typically be conducted in final design. One area is noted above (WRF) where low likelihood conditions may exist that could cause medium to high intensity effects, and that could potentially require additional mitigation pending further investigation to reduce the level of effects.

Operations and Maintenance

Varying amounts of permafrost thaw and subsidence would occur throughout the 28-year mine life pending the mine site component, localized subsurface conditions, and final construction and design practices. Permafrost disturbances associated with certain mine site infrastructure and more thaw stable areas (e.g., roads, buildings, processing facilities) would likely reach a nominal state of stability (equilibrium) during the operational period. Continued and/or permanent degradation of frozen soils are accounted for in stability analyses and thaw settlement design at mine facilities of critical importance, such as the TSF and WRF, which would reduce most permafrost impacts during operations to low to medium intensity levels.

Evaluation of GHG release scenarios and estimates associated with permafrost degradation during mine operation is presented Section 3.8, Air Quality.

As described above, frozen soils would be excavated from the toe of the WRF during construction. While less permafrost is expected at higher elevations at the WRF based subsurface site investigation programs and physical processes associated with permafrost occurrence (e.g., sunlight exposure and slope aspect, less insulative organic surface cover, substrate material types, etc.), isolated patches may exist that could affect the WRF as it expands upward in operations. Areas of localized instability upslope of the toe could result where excess ice and porewater pressures exist under loaded conditions in materials with poor permeability and drainage characteristics. Dispersion of potential high pore pressures would be variably addressed through bottom-up construction if the initial lifts of waste rock are sufficient to promote thaw drainage, which would be distributed via engineered rock drains beneath the WRF. If necessary, synthetic or natural materials may be necessary to prevent infiltration of fines into the rock drain. Hydraulic erosion and alteration of existing surface water drainage patterns could also result in some contribution to permafrost thaw during WRF operations. This effect would be minimized through surface water drainage controls to direct and contain contact water. The incremental effects of these issues in operations would be of low to medium intensity, i.e., the effects may or may not be noticeable, and design is generally adequate for conditions.

Permafrost occurs around the western rim of the open pit adjacent to Crooked Creek. Thaw settlement of ice-rich soils in this area during operations could lower the elevation of the narrow rim between the pit and Crooked Creek floodplain, and increase the likelihood that lateral erosion during a flood event could breach this barrier. A discussion of this potential effect is provided in Section 3.3, Geohazards and Seismic Conditions. A nominal value of 1 percent vertical strain or 10-foot reduction in the pit rim elevation was assumed in an analysis of these effects by BGC (2014c) without identifying thaw settlement as a separate causative factor. The potential effect of flooding/lateral erosion breaching this barrier would be of high intensity, but is generally considered low in likelihood based primarily on flood frequency analyses. Mitigation recommendations are also provided in Section 3.3, Geohazards and Seismic Conditions, to reduce the likelihood that this impact could occur.

Closure, Reclamation, and Monitoring

Permafrost degradation at the mine site begun during construction and operations would continue through closure and post-closure until thermal equilibrium is reached. While restoration of frozen soil conditions is not anticipated nor planned during closure, reclamation and revegetation of areas cleared of soils during construction would preserve remaining permafrost or slow the rate of degradation in the post-closure period and result in low intensity effects. The long-term effects of climate change on permafrost, which are likely to impede permafrost recovery, are discussed in Section 3.10, Vegetation.

Minor additional permafrost disturbances could occur during closure activities at the Crevice Creek spillway and WTP facilities. The WTP would be constructed in an area of previously disturbed soils on a ridge with little permafrost; thus, incremental impacts on permafrost at this facility would be of low intensity. The Crevice Creek spillway would be located in the upper Anaconda Creek valley where only isolated occurrences of permafrost are expected, and the intensity of effects would also be low.

Summary of Mine Site Impacts

Impacts to and from permafrost at the mine site during construction, operation, and closure of Alternative 2 would range from low intensity (e.g., little noticeable ground settlement) to medium intensity (e.g., complete removal of permafrost soils, progressive widespread thaw settlement across the Anaconda Creek valley bottom over the operational period), although specific low probability conditions may exist that could cause medium to high intensity effects which could be reduced through additional mitigation. Effects on permafrost would be localized beneath facility footprints and cleared areas. Permafrost thaw effects would range from long-term (e.g., unstable foundations reach equilibrium within life of mine) to permanent (i.e., restoration of permafrost not expected). Discontinuous permafrost is considered common in context based on its regional distribution.

Transportation Facilities

Construction

Evaluation of permafrost impacts at transportation facilities are limited to components where frozen soil conditions are known to exist. This would include the mine access road, Angyaruaq (Jungjuk) Port site, Kuskokwim River corridor, and Bethel Port site as described below. These components are located in the regionally extensive discontinuous zone of permafrost in Alaska, the context of effects is considered common. The Dutch Harbor Port site is located in an area that is considered free of permafrost. Evaluation of GHG emissions resulting from permafrost degradation is presented Section 3.8, Air Quality.

- *Mine Access Road:* The presence of permafrost along the road alignment is generally limited to intermittent segments near Juninggulra Mountain, the North Fork of Getmuna Creek, Angyaruaq (Jungjuk) Creek area, and the Angyaruaq (Jungjuk) Port site. These areas of the road comprise less than about 5 miles of the total road length. Frozen fine-grained soils that extend approximately 0.3 miles north from the port site are considered extremely unstable, coincide with active thermokarst terrain, and would likely result in significant settlement (Recon 2011a). These conditions would typically be managed to low to medium intensity levels through special design in the final engineering stage of the Project. Proposed road design features would address thaw consolidation of moderate ice content, fine-grained soils, which could potentially settle up to approximately 3 feet. Construction practices that generally include placement of geotextile materials over existing ground cover, followed by placement of a suitable lift of imported material, are expected to reduce the severity of thermokarst effects to low intensity. These effects would be localized within the immediate vicinity of the road footprint, and could extend long-term beyond the initial construction period of 0.5 to 1.5 years. The initial phase of construction would occur during winter months, and would be monitored as described below under Operations and Maintenance. The nature and extent of permafrost near Juninggulra Mountain and Getmuna Creek is such that the road can be constructed using conventional fill techniques (Recon 2011a).
- *Angyaruaq (Jungjuk) Port:* Isolated areas of permafrost occur in the southwest corner and northeast side of the port footprint, and do not appear to extend below depths of 10 to 30 feet. No permafrost has been encountered below the fuel storage tank footprint (Recon 2013b; BGC 2013h). Marginal soil conditions and shallow permafrost-bearing soils

would likely require limited excavation and placement with suitable fill materials. While these details have not been specified as part of Alternative 2 yet, it is reasonable to assume that they would be addressed in final design. Excavated permafrost materials would likely be placed in the engineered 5-acre stockpile and consolidated with both organic/mineral soils from port clearing activities and saturated river sediment excavated from the berth area. The stockpile would be situated on relatively level thaw-stable ground on the upland side of the port away from waterbodies and wetlands, and constructed with low sloping profiles. While ESC design features specific to thawing permafrost soils (such as a sediment pond) have not been defined yet for the stockpile, it is reasonable to assume that these would be addressed in final design as part of SWPPP permitting, such that the likelihood of sediment-laden runoff flowing towards the Kuskokwim River is considered low.

- *Kuskokwim River Corridor:* The Kuskokwim River is in the discontinuous zone of permafrost, and permafrost melting is considered one of two main riverbank erosion mechanisms. The primary means permafrost thaw and subsequent erosion is attributed to a process called “thermo-erosional niching” which is addressed further in Section 3.5, Surface Water Hydrology. Although wakes from barge traffic could appreciably contribute to permafrost degradation during ice free barging seasons, other natural processes and variables influence permafrost degradation such as slope bank aspect, warm water eddies during summer months, and prevailing wind wave action (Dorava and Hogan 1995). Since barge induced waves are not expected to substantially impact Kuskokwim River bank erosion rates, subsequent effects to river bank areas where permafrost exists are also expected to be minimal in comparison to existing processes.
- *Bethel Port Site:* The top of permafrost in the vicinity of the proposed Bethel Port site ranges from 3 to 50 feet below ground surface, and could potentially be encountered during construction of the 16-acre facility depending on distance from the river (thaw bulb) and amount of previously disturbed soils. Much of Bethel is built on pile foundations due to shallow permafrost conditions. While site preparation and construction details are currently unavailable for this third-party site, it is reasonable to assume that site-specific excavation and/or special design would be completed during final engineering, such that effects from thaw unstable soils and thaw settlement would be of low to medium intensity (design adequate for conditions).

Operations and Maintenance

Since no additional development is planned during transportation facilities operation, impacts would be limited to continuing low to medium intensity permafrost thaw effects described above under Construction. Thaw settlement along the mine access road would be monitored continuously with ongoing traffic throughout mine construction and operations. It is possible that permafrost thaw (where present) would reach a state of equilibrium during the 28-year period of mine site operation.

Corrective actions would be implemented as needed based on post-construction inspections in permafrost affected areas. Due to the limited presence of permafrost along the proposed road alignment and planned mitigation in design, continued stabilization or rehabilitation activities are expected to be isolated and minimal. Measures to repair thaw effects would include placement of fill from borrow material sites and correction of drainage problems derived from

thermal subsidence. Where appropriate, temporary and long-term ESC measures would be installed as described in Section 3.2.3.2.4.

Closure, Reclamation, and Monitoring

Anticipated closure and termination activities would be limited to the Angyaruaq (Jungjuk) Port since the mine access road would remain indefinitely to support monitoring and the pit lake water treatment plant operation, and the Bethel Port site would likely continue to operate under third-party ownership. Permafrost effects for the mine access road would be the same as described above under Operations and Maintenance.

Most of the Angyaruaq (Jungjuk) Port facility would be reclaimed following mine site closure, and infrastructure removed that is no longer required to support post-closure monitoring and water treatment. Surfaces would be graded, contoured, and revegetated as necessary for surface stabilization. Recovery of permafrost conditions at the port site is not expected to occur, although reclamation would likely preserve remaining permafrost or slow degradation.

Summary of Transportation Facilities Impacts

Permafrost impacts at transportation infrastructure facilities during construction, operation, and closure of Alternative 2, such as thaw settlement along short road segments or erosion and sedimentation of thawing soils at the Jungjuk port stockpile, are expected to be of low to medium intensity, assuming that impacts are effectively managed through planned special design. The geographic extent of effects would be localized within the immediate vicinity of infrastructure footprints. Most permafrost thaw effects would range from long-term (e.g., road conditions reach equilibrium within several years) to permanent (i.e., restoration of permafrost not expected). Discontinuous permafrost is considered common in context based on its regional distribution.

Natural Gas Pipeline

Construction

The proposed 315-mile long pipeline route crosses an estimated 31 miles of discontinuous permafrost: about 19 miles of thaw stable permafrost soils, and 12 miles of thaw unstable soil conditions that are expected to settle more than 1 foot when thawed over time (SRK 2013b; Fueg 2014) (Section 3.2.2.3.2, Figure 2.3-34). Permafrost occurs intermittently between MP 100 and MP 150 in the Alaska Range, and ice-rich soil conditions extend along the north flank of the Alaska Range between about MP 150 and MP 215. Approximately 30 proposed stream crossings coincide with permafrost and fine-grained soils potentially susceptible to thermal erosion (Section 3.2.2.3.3, Table 3.2-9). Extensive bodies of massive ground ice have not been documented based on preliminary geotechnical investigations. Overall, the context of permafrost effects is considered common, based on the pipeline route traversing the regionally extensive discontinuous permafrost zone, and the presence of pre-existing thermokarst terrain along segments of the route.

Permafrost effects pertinent to pipelines include differential thaw settlement and thermal erosion. Differential thaw settlement can have long-term effects on pipeline integrity and drainage patterns. Thermal erosion commonly occurs when soil cover over permafrost is removed, triggering melting and erosion. These effects can start immediately following clearing

and/or soil removal during construction and last for years. All GHG emissions derived from permafrost degradation along the natural gas pipeline route (construction and operation) are presented in Section 3.8, Air Quality.

Disturbances to frozen soil conditions are primarily associated with invasive pipeline construction activities and disturbances to the subsurface thermal regime via heat transfer along the pipeline trench and cleared ROW. Conditions generally considered most susceptible to thermal erosion include areas of massive ground ice where the soil moisture content (ice) is greater than 250 percent of the dry weight; disturbed ice-rich soils adjacent to water bodies; and areas of exposed ice-rich soils along cut slopes that could potentially result in thaw flow slides, gullying, subsidence, and surface water ponding (Davis 2001; SRK 2013b). These conditions would likely be most susceptible to retrogressive thaw slumps, and would have the greatest potential to occur during the first season of thaw following construction, but could also be cyclic with additional headwall retreat in subsequent years. Other construction disturbances that would influence immediate or prolonged thermal erosion of ice-rich soils include drainage pattern alteration, excavation, and removal/disturbance of insulative vegetation cover.

Edges of water bodies (stream crossings and wetlands) would be more susceptible to retrogressive thaw where ice-rich frozen soil conditions exist. Conditions influencing the severity of thaw at these areas include the amount of construction disturbance, slope gradient, soil texture (fine-grained versus coarse-grained materials), permafrost stability, and stabilization and restoration measures.

The types of impacts described above would generally be of low intensity in thaw stable soils, and medium to high intensity in thaw unstable soils without the application of planned mitigation (Table 3.2-11). Construction of the pipeline and off-ROW facilities would incorporate the following specialized design, BMPs, and ESC measures to minimize and mitigate thaw settlement and thermal erosion (SRK 2013b). The use of these features and practices is expected to reduce permafrost effects to low to medium intensity levels in thaw unstable soils.

Pipeline Design

There are approximately 316 mapped transitions between thaw unstable soils and either thaw stable or non-permafrost soils. These transitions are more likely to result in adverse thaw settlement or differential ground movement that could subject the pipeline to additional strain. The pipeline would require design considerations and safety conditions beyond the requirements of the present gas pipeline code (49 CFR Part 192) in order to safely utilize strain-based design (SBD). Under PHMSA regulations, SBD may be considered where high longitudinal strain caused by special geotechnical conditions, such as frost heave or differential thaw settlement, can safely stress the pipe beyond the typical elastic range allowed by SBD. The results of thaw modeling used in assessing the need for SBD are described below under Operations and Maintenance. Additional description of the purpose and need for SBD, as well as geohazard and environmental conditions that PHMSA uses to evaluate the likelihood of pipeline failure as a result of SBD, are described in the attached Donlin Gold PHMSA Special Permit Conditions and Environmental Analysis Report (Appendix E).

Mitigation in areas where strain is anticipated to approach or exceed 0.5 percent would include project-specific design parameters, pipeline materials, construction, and O&M practices described as conditions in the PHMSA Special Permit. An SBD conditions document (that becomes part of the Special Permit) would include an SBD Plan that addresses these

specifications and procedures. While extensive continuous bodies of massive ground ice have not been documented along the pipeline route based on preliminary geotechnical investigations, additional geotechnical work would be performed prior to construction to re-evaluate ice contents along the trench line for final design planning. Based on the results of additional geotechnical work, final design and construction considerations could include, for example, special wall thickness, weld specifications and x-ray inspections, welder training requirements, and insulation of specific sections of pipe to reduce subsurface heat transfer. A summary of mitigation measures and conditions that would be implemented during design, construction, and operations is provided in Appendix E. These are expected to manage the effects of permafrost thaw settlement on pipeline integrity to a medium level of intensity Table 3.2-11.

Pipeline Construction

Season of Construction: Approximately 68 percent of the total pipeline length would occur during frozen winter conditions to accommodate support equipment and minimize disturbances to permafrost. To the extent practicable, summer or fall construction would be limited to favorable geotechnical conditions such as stable permafrost and/or suitable near surface soils to support equipment (i.e., gravel floodplains, bedrock, etc.). Additional considerations would include terrain and work length (pipeline) continuity.

ROW: Working surfaces would be narrower (smaller) adjacent to the pipeline work area to minimize cuts in thaw-unstable permafrost. Work pads would be constructed of snow and ice in thaw unstable areas when possible. In addition, frost packing would be performed to facilitate frost penetration (at depth) to accommodate equipment in soft soil conditions. Where applicable, imported gravel fill would be used for winter work pads on side slopes in the absence of snow and ice pads. To minimize thermal regime disturbances, organic layers would remain undisturbed below gravel work pads left in place. Land clearing activities would be limited to essential construction areas only, and surface vegetation removal would be avoided where possible.

Trenching: Compressible surface organic material would be segregated during excavation of the trench line and stockpiled separately in windrowed spoil piles from mineral soils for use in final cover and reclamation of the trench line. Near vertical trench cuts would be made in ice-rich fine-grained soils to minimize disturbances, and pipe installation would occur immediately. Ice-rich soil would be segregated from thaw stable soil, in addition to over-excavation of massive ice or high ice content soils to a depth of 10 feet below the bottom of the trench. Removed materials would be replaced with thaw stable bedding and backfill. Segregated ice-rich soils would be stockpiled as described below. Surface completion material spread (roached) over the trench line would be mounded to compensate for future settling associated with melting, water channelization (run off), or ponding. It is possible that dewatering activities may be necessary during trenching activities due to the influx of water from taliks (unfrozen thaw bulbs surrounding permafrost).

Temporary Soil Stockpiles (Ice-Rich): During trenching, ice-rich excavation spoils would be segregated due to the potential release of water upon thawing. Segregated ice-rich soils would be stockpiled and allowed to thaw and drain prior to reuse as construction material. Stockpiles would be located downslope of the ROW, on thaw stable ground, and a minimum of 30 feet away from water bodies or wetlands. Management of ice-rich stockpiles to minimize erosion would include low sloping profiles, surface roughening, silt fencing and wattles around inactive

stockpiles, and plastic covering if there is an increased risk of runoff or high-risk weather conditions. After draining, the material would be spread (roached) over the trench line as surface completion material, or remain stockpiled for future use.

ESC Measures: Temporary and long-term ESC measures would be installed during and immediately following construction. Those pertinent to permafrost areas may include ground insulation or thermal blankets, earthen berms, and silt fences. Cuts in thaw unstable permafrost would generally be near vertical and patched with saved organic material and/or allowed to self-repair as thaw progresses and the uphill vegetative mat lays over the cut surface. Cuts may also be addressed through slope modification and placement of ESC measures where practicable. Stream banks in permafrost areas would be laid back and patched. Extensive silt fencing or other sediment barriers would be installed at the base of thaw unstable cuts. Silt fencing or other ESCs would also be placed along lengths of finished trench line in areas of thaw unstable soil as a precautionary measure. Appropriate temporary ESC measures would be employed to manage trench dewatering activities as described in Section 3.2.3.2.1.

Water Body and Wetland Crossings: Water bodies and wetlands are generally considered environmentally sensitive areas that would require additional precautionary ESC measures to mitigate soil erosion. Approximately 30 proposed pipeline stream crossings are located in fine-grained permafrost soils that are considered particularly vulnerable to erosion and approximately 20 of these have known or potential fish habitat (Table 3.2-9). Impacts and mitigation measures associated with fish are addressed in Section 3.13, Fish and Aquatic Resources. The following BMPs and ESC measures would be implemented at water body crossings and wetlands in permafrost areas as necessary:

- Installation of pipeline at most water bodies and wetlands during winter months when frozen ground and snow are present;
- Wetlands clearing would be limited to cutting vegetation flush with the ground, and stump removal would be limited to the trench line;
- Trench plugs would be used to prevent sediment from entering the water body, and decrease erosion of backfill material;
- Trench breakers would be placed above and below wetlands situated on sloping terrain;
- Excavated material would be compositionally segregated (organic vs. non-organic), salvaged, and backfilled in reverse order of removal to minimize groundwater flow and permafrost disturbances;
- As described above, excavated spoils would be placed a minimum of 30 feet from the receiving water body or wetland, and spoils that have no immediate use would be removed from the area and stockpiled at a designated prepared area;
- Where melting permafrost generates water in the trench, dewatering activities would incorporate filter bags for sediment removal prior to discharging to an energy dissipater or well established vegetation;
- Erosion control matting would be used to armor shorelines and approaches;
- Slope breakers would be installed upslope of the water body or wetland to reduce runoff and divert water to the surrounding terrain (as suitably determined);

- Wattles, silt fences, brush berms, rolled erosion control products (RECPs), or a combination of these would be installed parallel to shorelines across the entire construction ROW for erosion control and containment;
- Temporary silt curtains would be installed on an as-needed basis during active construction as a turbidity barrier to receiving waters;
- Graded banks would be covered with erosion control mats or RECPs, and banks would be graded to approximate original configurations, or a more stable configuration than pre-existing conditions;
- Finish grading would account for surface water ponding and revegetation efforts; and
- Temporary ESC measures would remain in place until stabilization (revegetation) has sufficiently progressed to prevent erosion and sediment migration to the water body.

Post-Construction Reclamation: For winter activities, a cleanup crew would prepare the ROW for breakup once the pipe is laid, followed by a reclamation crew in summer. The reclamation crew would inspect the ROW in permafrost areas in the first summer season following winter construction to address thermal erosion problems that may have developed during the first breakup season. In summer-construction sections, the reclamation crew would follow behind the ESC crew in the same summer. Summer post-construction inspections and corrective actions for most of the pipeline without permanent road access would be accessed and mobilized via ORV, walking, aerial means, and/or watercraft. Additional reclamation/cleanup crew functions, monitoring/maintenance activities, and schedule are further addressed in Section 3.2.3.2.4.

Operations and Maintenance

Since no new or expanded infrastructure (airstrips or roads) are planned during pipeline operation, impacts to permafrost during this phase would be from the continuation of thaw effects initiated during construction and use of the pipeline. Although the pipeline would operate near seasonal ambient ground temperatures and is not expected to freeze surrounding soils, subsequent heat transfer and ongoing effects in areas of disturbed surface soils could facilitate permafrost thaw and settlement in thaw unstable soils.

Thermal Modeling: Pipeline thermal modeling was performed to evaluate thaw settlement and pipeline wall thickness due to buried thermal regime conditions (CH2MHill 2011a 2011b; Fuego 2014; Zarling 2011). Datasets included ground temperature thermistor information and soil type information acquired during geotechnical investigations along the proposed pipeline alignment. The analysis and subsequent thaw profile predictions were conducted using available weather data and thaw model for the anticipated 30-year design lifespan.

The model was run using historical annual temperatures from Farewell Lake. Model runs under climate change scenarios are described in Chapter 4, Cumulative Effects. Freezing and thawing factors (n-factors) were adjusted during the last 10 years of the simulation to account for revegetation of disturbed areas. Two different n-factors were run to simulate different snow thicknesses, and two soil profiles considered typical were analyzed for both n-factors. The modeled profiles were symmetrically aligned 70 feet wide on either side of the pipe centerline and the model was run to a depth of 50 feet.

The results of the analysis and associated scenarios by Zarling (2011) yielded predicted thaw depths beneath the disturbed ROW and trench ranging from 4 to 29 feet over 30 years; results using an updated version of the model using only the thin organic layer profile resulted in a predicted thaw depth of 27 feet (Fueg 2014). Conditions affecting thaw depth variability include soil type, moisture content, atmospheric conditions, vegetation, snow cover, and degree of disturbance attributed to construction.

Permafrost acts as storage for carbon contained in organic soils, which can be released to the atmosphere in the form of carbon dioxide and methane upon thawing (e.g., O'Donnell 2010; Tarnocai et al. 2009). Estimates of greenhouse-gas (GHG) emissions from melting permafrost caused by the project are provided in Section 3.8, Air Quality, along with a description of the level of intensity of the impact. For the pipeline, these estimates are based on a soil bulk density of 1.6 g/cc for silty permafrost soils (USDA-NRCS 2013; Zollinger et al. 2013), and assume that thawing is initiated across the full construction ROW (150 feet) and continues over the life of the mine to the 27-foot predicted thaw depth for operations (Fueg 2014). Based on these assumptions, about 33 million tons of permafrost soils are predicted to thaw during the operations period.

Based on the updated modeling results, thaw settlement at permafrost locations along the pipeline was estimated to range from 0 to 21.1 feet at the ground surface, and 0 to 20 feet below the pipe. Of 132 geoprobe holes drilled in frozen soils and analyzed in these studies, about 70 percent showed little to no thaw settlement (i.e., settlement of 0 to 1 foot), and only three showed extreme settlements exceeding 10 feet. The latter are located along the Threemile Creek/Jones River portion of the alignment near MPs 115 to 120, in an area with additional geohazards such as slope instability where specialized construction techniques (e.g., HDD or deep bedrock trenching) are proposed that would also address concerns about thaw settlement (Fueg 2014). Thus, the primary area of concern for thaw settlement would be on the north side of the Alaska Range between the North Fork Kuskokwim River (MP 147) and the main stem Kuskokwim River (MP 240). About 37 percent of geoprobe holes in this area contain permafrost, with thaw settlement estimates ranging from 0.1 to 7.3 feet at ground surface, and 0 to 5.3 feet below the pipe. These percentages and settlement estimates are considered conservative, in that the geoprobes specifically targeted areas of suspected ice-rich permafrost, and those which hit refusal at depths shallower than the estimated thaw depth were assumed in the model to continue with the final soil layer logged, even though refusal on something other than frozen soils (such as boulders or bedrock) would be less likely to contain deep permafrost.

The effects of differential settlement below the pipe on pipeline integrity would be addressed through PHMSA Special Permit conditions as described above under Construction and in Appendix E. Conditions specific to the operations period could include, for example, in-line tool inspections, strain gages in problematic segments, and frequency of PHMSA reviews. The effects of settlement at the ground surface during operations, which could lead to medium to high intensity adverse changes in drainage patterns and erosion if not mitigated, would be addressed primarily during construction by placing a mound of fill over the trench to allow for settlement. Additional fill may be required in some areas on an ongoing basis through proactive monitoring and maintenance as described below. These actions are expected to reduce the level of effects to low to medium intensity.

Thermal Erosion: Thermally unstable conditions at areas with unique physical settings (e.g., massive ice, slope cuts, water bodies) would likely result in multi-year (long-term) stabilization

and restoration efforts to address subsidence, thaw flow slides, or other construction-induced thermokarst processes. Thaw settlement in areas of ice-rich permafrost along the ROW could result in altered drainage patterns and erosion where runoff flows into and out of subsided zones. The geographic extent of thermal erosion over the life of the mine would be mostly localized within the immediate vicinity of the ROW. Retrogressive thaw slumps of cut slopes along the pipeline would be evaluated on a case-by-case basis. Areas with exposed ice-rich, fine-grained permafrost could result in isolated cases where sedimentation reaches downstream water bodies. However, planned mitigation measures at or near water body crossings, described under Construction, are expected to be largely effective in maintaining effects to medium intensity.

Monitoring and Maintenance Activities: Routine monitoring and surveillance activities would address areas of thaw-induced erosion or settlement and identified deficiencies during operations. Monitoring frequency would be based on prescribed inspection intervals, or as needed to address unique soil stabilization conditions. More intensive multi-year surface stabilization measures would be required on a limited as-needed basis at discrete locations that are more susceptible to thermal erosion, such as areas with cuts in unstable permafrost slopes and fine-grained ice-rich soil conditions near water bodies and wetlands, where cleanup of melted material behind sediment barriers would be conducted. Because most areas of the pipeline lack permanent roads, access for monitoring and rehabilitation would be by aerial means, walking, ORV and watercraft in the summer and snowmachine in the winter (SRK 2013b).

Stabilization measures would be conducted in accordance with the SRR Plan. Measures to reduce permafrost thaw and facilitate reestablishment of seasonal active layers and thaw equilibrium would include placement of backfill or other form of ground insulation, natural rehabilitation, or RECPs, as appropriate and practicable. High disturbance areas would be well documented, routinely monitored, and corrected accordingly. It is likely that thermal erosion stabilization measures along most segments of the pipeline would eventually achieve a general state of equilibrium by the closure and termination phase, given the projected 30-year period of pipeline operation. These measures are expected to reduce areas of medium to high intensity thaw erosion to low to medium levels.

Closure, Reclamation, and Monitoring

Effects on permafrost during closure and termination would be comparatively limited due to the sizeable portion of in-place pipeline abandonment; use of previously stabilized/restored work surfaces and trench mounding from pipeline construction and operation activities; and a revised SRR Plan that would incorporate BMPs and ESC/restoration measures based on review and modification of prior practices in permafrost areas.

The pipeline thermal model (described above under Operations and Maintenance) was run for an additional 45 years beyond termination to evaluate the effects of continuing thaw settlement in areas of concern during the post-closure period. An additional 10 feet of thaw depth was predicted to occur over this period to a total depth of 37 feet (Fueg 2014). Assuming that the additional thawing in post-closure would occur across the 50-foot operations ROW, the additional amount of permafrost soils affected over 45 years post-closure would be on the order of 4 million tons. Estimates of GHG emissions and the level of effects from melting permafrost during both operations and closure are provided in Section 3.8, Air Quality.

Discounting areas of extreme thaw settlement in the Alaska Range, which would be addressed through specialized construction techniques, modeling results indicate that additional post-closure settlement in the area of unstable permafrost along the north flank of the Alaska Range would occur in about 14 percent of boreholes in this area. The amount of incremental settlement is estimated to range from 0.2 to 1.7 feet at the ground surface (Fueg 2014). Ongoing assessment during the 30-year operations period is expected to provide a more accurate indication of the potential for post-closure thaw settlement that would be incorporated into the revised SRR Plan prior to closure.

Thus, impacts to previously disturbed permafrost areas are likely to persist on a localized case-by-case basis following pipeline closure. These circumstances would be addressed per the revised SRR Plan, which would be composed specifically for closure and termination activities, but would not necessarily cover thaw settlement restoration by Donlin Gold in the post-closure period. The intensity of effects and monitoring/stabilization measures are expected to be mostly similar to those described under Operations and Maintenance, likely consisting of visual inspection during overflights and placement of additional fill and/or other erosion control measures as needed, although localized high intensity effects could occur in the absence of periodic monitoring/stabilization in post-closure. Mitigation recommendations are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation, for permit conditions that could require that these activities be performed in the post-closure period to reduce any localized effects to medium intensity.

Summary of Natural Gas Pipeline Impacts

Permafrost impacts along the pipeline during construction, operation, and closure of Alternative 2 would range from low intensity (e.g., little noticeable ground settlement or thermal erosion) to medium intensity (e.g., pipeline design and BMPs expected to be effective at controlling intermittent noticeable settlement or thermal erosion), although specific conditions may exist in post-closure that could cause localized high intensity effects which could be reduced through additional mitigation. The geographic extent of effects would be localized along intermittent ice-rich areas (mostly along the north flank of the Alaska Range) and within the immediate vicinity of infrastructure footprints. Most permafrost thaw effects would range in duration from long-term (e.g., settlement reaches equilibrium within several years) to permanent (i.e., restoration of permafrost not expected). Discontinuous permafrost is considered common in context based on its regional distribution.

3.2.3.2.3 EROSION

Mine Site

Both hydraulic (water) and wind erosion are anticipated to occur at the mine site throughout construction, operation, and closure/reclamation. Erosion can cause adverse effects on downgradient water quality, streams, wetlands, and other sensitive areas outside the project footprint through the breakdown of soil particles and transport of sediment, particularly during storm events, if not managed through the use of ESC measures that stabilize soil, control runoff, capture moving sediment, and promote revegetation. Plans and programs that describe activities related to the control and mitigation of erosion at the mine site, and which are considered part of the project under Alternative 2, are described in Appendix F. Activities

resulting in erosional disturbances throughout mine development and closure would be conducted in accordance with an approved project SWPPP. Other plans applicable to the mine site include the *Plan of Operations* and related *Monitoring Plan* (SRK 2012a, c) which address surface water runoff and drainage control systems incorporated into mine design, operations, and compliance monitoring. Reclamation activities and erosion control measures would be performed throughout development, operation, and closure activities for the proposed mine site. To the extent practicable, concurrent reclamation would be performed as locations/areas are no longer required or reach design life criteria.

Construction

Most soil conditions located at the mine site are generally considered to have a slight hazard of erosion by water (with the organic mat removed) (Table 3.2-1, Figure 3.2-1). Three of the four major soil components associated with soil map unit R30FPA, which covers most of the mine site, are considered to have moderate hazard of erosion by air, whereas one component is considered to have a slight hazard of erosion by air. Soil profiles associated with this soil map unit typically include a surficial peat layer overlying varying fractions of silt-sand mixtures, which is underlain by gravels, and/or silt-sand mixtures.

Other soil types at the mine (map unit R30MTC) are limited to a small portion of the pit and terrace gravel material sites that would provide bedding material for TSF construction. The hazard of erosion by water for this map unit ranges from slight to severe, and the hazard of erosion by air ranges from slight to moderate. Soil profiles typically include a surficial peat layer overlying either gravel rich materials with varying fractions of silt and mixtures, or uniform mixtures of sand and/or silt. The erodible soils exposed during construction in most of these areas would either be completely removed during mine development and/or covered by overburden and growth medium stockpiles.

Mine site activities over the 3- to 4-year construction period would occur year round, of which little erosion or no erosion is anticipated during winter months. The greatest potential for soil erosion would likely be during spring breakup from snowmelt, or from June through October from rainfall and surface water runoff.

As described in Section 3.2.3.2.1 (Soil Disturbance/Removal), large quantities of overburden material would be removed during development/construction of the mine pit, WRF, TSF, and engineered stockpile storage areas, resulting in temporary destabilization of ground surfaces throughout the construction period and potential secondary effects on downgradient water quality (Section 3.7, Water Quality) if not controlled. Exposed soils would be particularly vulnerable to ongoing hydraulic and wind erosion processes where not covered by constructed facilities. Erosional sources of varying significance include stockpiled overburden, road construction, and development of facility foundations. Overburden removal, fill material placement, grading, and contouring activities conducted using heavy equipment such as loaders, dozers, excavators and graders would contribute to wind erosion.

While most soils at the mine site may be more tolerant to hydraulic erosion than wind erosion based on the NRCS data, the intensity of both types of erosive effects during non-winter construction is anticipated to be medium to high due to the large areal extent of disturbed surfaces; however, effects are anticipated to be reduced to low to medium levels through proposed design features and BMPs similar to those applied during pipeline construction, that would minimize erosion during construction. Much of the surface water and erosional runoff

associated with major mine facilities would be intercepted and contained. This would typically include mine site “contact water” or “non-contact water” recycled or captured for use in the processing plant or treated and discharged. Drainage controls would include alteration and channeling of surface water drainage through underdrains and diversion ditches that would otherwise contribute to hydraulic erosion.

The geographic extent of erosion is considered local, in that design features and ESC measures described below are expected to keep potential effects within the immediate vicinity of mine facility footprints. Erosion effects are considered common to important in context, in that they impact common soil and water resources, but are also natural hazards governed by regulation Table 3.2-11. Descriptions of potential or anticipated soil erosion scenarios during construction are provided below for major mine site components, along with planned site-specific mitigation measures to control erosion (SRK 2012a, b).

Pit Clearing: Overburden stripping during pit development could lead to erosion within the pit. Runoff would be captured and treated as mine drainage contact water. This water would be directed using berms and pumped to the Lower Contact Water Dam (CWD) or alternatively to the pit or Rob’s Gulch depending on the period of development.

Pit Dewatering Water Discharge: Discharge of treated dewatering water to Crooked Creek below Omega Gulch could cause erosion if not controlled using BMPs. The outfall structural design and location relative to exposed soils, stream banks, and existing flow would be determined during detail engineering prior to construction. Energy dissipators, erosion control measures, and methods for seasonal adjustments to prevent icing and scour would be identified and installed as need to meet stormwater and water quality requirements (Fernandez 2015).

Ore Stockpile and Process Plant: To prevent discharge of contact water to Crooked Creek during the first year of construction, a containment berm and pump system would capture runoff from the ore stockpile. Contact runoff from the ore stockpile thereafter would report to the American Creek Magnetic Anomaly (ACMA) Pit once progressive pit expansion intersects American. Surface water runoff downgradient of the ore stockpile berm would discharge to the ACMA pit and be collected as described above. The potential also exists for adverse impacts to soil and air quality from wind erosion creating dust at the ore stockpile. These effects are described in 3.2.3.2.1, and Section 3.8, Air Quality. Anticipated impacts are expected to be limited due to planned mitigation measures. Mitigation measures include relatively short transport distances between the pit, ore stockpile, and process plant, minimizing the potential for dust dispersion. Water and surfactants would be applied to haul roads for dust control. Fugitive dust baghouses would control potential emissions at transfer points during crushing. Coarse ore would be stockpiled in an enclosed-steel framed structure to control dust. Subsequent grinding stages would occur within closed systems for slurry production. Additional mercury abatement and emission control systems in the process plant are described in Section 3.8, Air Quality.

Overburden Stockpiles: The NOB, SOB, and TSF overburden stockpiles would be constructed with sediment and runoff control structures. Design features would include upgradient diversion channels intercepting runoff to the stockpiles, and drainage ditches and sediment collection ponds downgradient of the stockpiles to collect runoff and seepage. Collected water from the SOB stockpile could be pumped to the Lower CWD and then managed as contact water.

TSF: Design features that would mitigate erosion and control sedimentation during TSF construction include the following:

- An aggressive temporary construction schedule would limit the amount of time that excavated surfaces are exposed;
- A TSF starter dam would be completed during the first winter of construction, impounding water from the upstream side of the TSF dam;
- A top-down method of slope excavation would be conducted, and slope angles of 2.5H:1V (horizontal to vertical) would be maintained to minimize erosion. Slope angles would be adjusted accordingly based on geotechnical engineer determinations during construction;
- Diversion channels for surface water runoff control on the north and south sides of the TSF would be completed during the first winter of construction, and the North and South Freshwater Diversion Dams (FWDDs) that would serve as cofferdams during TSF starter dam construction and liner placement. Diversion channels would be lined with 1.0-mm high-density polyethylene (HDPE) over a layer of riprap protection in overburden materials to prevent channel erosion and reduce ground infiltration. No liner would be installed in channel areas with a bedrock substrate;
- The impoundment area would be stripped of vegetation and overburden winter construction when soils are frozen. Freshwater diversion channels would be completed prior to summer to minimize erosion in the impoundment area during liner bedding material placement by intercepting and diverting runoff around the impoundment area; and;
- TSF underdrains installed in the summer following overburden removal would help control runoff and drain permafrost melt away from stripped overburden surfaces.

WRF: Minimal soil removal and erosion is expected during construction of the WRF. Overburden stripping and removal would be limited to the Lower CWD, landslide stabilization berm (LSB), and ice-rich materials along the toe of the WRF. Most of the WRF would be constructed from the bottom up along the American Creek valley and placed on top of existing soil surfaces. The initial phases of water collection, diversion measures (e.g., Rob's Gulch), and rock drains would be completed during the first pre-production year of construction to control runoff. Construction of the American Creek FWDD would be completed about 6 months before completion of the Lower CWD to serve as a cofferdam and intercept and divert runoff. The LSB would be constructed of chemically inert durable rock fill for slope stabilization.

Earthwork: A variety of measures would be implemented during earth-moving activities at the WRF lifts and large overburden stockpiles to control surface water run-off, infiltration, and potential erosion. Surface grading practices would include crowning or in-sloping of running surfaces of successive lifts to control runoff and erosion. Interim stockpile surfaces would be revegetated for surface stabilization, and/or surfaces would be progressively reclaimed throughout operation.

Material Sites: As noted above, erodible soils exposed during construction at most of the material sites would either be completely removed during mine development and/or covered by overburden and growth medium stockpiles. Specific plans for ESC measures at material sites not subsequently covered by overburden stockpiles are not provided in the current Donlin Gold

Plan of Operations, but are expected to be included in the site-wide SWPPP. Development methods at material sites would range from surface ripping to drilling and blasting, depending upon material competency. In all circumstances, overburden will be stripped and salvaged during initial development for eventual reclamation. Sites would be excavated in stages meeting immediate demands to minimize disturbance areas and erosion potential. Management of temporary overburden and material stockpiles will consider the composition of the materials (e.g., organics, mineral soil, permafrost), local terrain, and include BMPs and ESC measures as described in Section 3.2.3.2.3 (Natural Gas Pipeline). Anticipated material site development and reclamation practices are further described under Transportation Facilities (Section 3.2.3.2.3), and site-specific design features pertinent to these mine components are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation.

Roads: Construction practices for roads would incorporate BMPs for stormwater control. These would be addressed in a SWPPP detailing appropriate use of ESC measures (e.g., silt fences, hay bales, sedimentation basins, and brush berms). Both general purpose mine roads and construction roads would be equipped with 3-foot wide drainage ditches and 23-foot wide safety berms (BGC 2011e). Surficial organics, loess, and ice-rich materials would be stripped and stored on the downslope side of roads or hauled to the NOB stockpile. Road subgrades would be graded and leveled, and constructed of suitable imported fill materials meeting road design requirements. Water trucks for dust control would be used to spray roads and working areas as needed to control wind erosion.

Operations and Maintenance

Erosion effects during mine operations would be comparatively less than during construction due to less soil removal, on-going reclamation and surface stabilization, operational drainage design features, and ongoing monitoring for compliance with SWPPP requirements. A major component of the operational period would include concurrent reclamation activities at the WRF and other areas no longer required for active mining. Since on-going reclamation and surface stabilization would be performed throughout the mine life, the anticipated intensity of effects is considered low to medium, assuming that planned rehabilitation/revegetation criteria are met for reclaimed surfaces. Planned design features and potential conditions unique to specific mine components during operations are described below.

- *WRF Stability/Erosion:* Erosion or sedimentation could potentially result from failure of localized unstable portions of the WRF if too much overburden is mixed with waste rock. Design calculations indicate that overburden placed in the WRF throughout operation should not exceed an overburden-to-waste rock ratio of 20 percent to avoid instability. Current plans would include an 8 percent mixture of overburden by volume on an annual basis, which is below the calculated potential instability threshold. Additional efforts would also include overburden/waste rock mixing processes and selective placement of materials to maximize stability. Various types of overburden and waste rock would be mixed to achieve suitable strength characteristics during placement in the WRF. Materials would be distributed as such to minimize pore pressures, and selectively placed in non-structurally sensitive areas. Surface swales and/or ditches would direct flow to rock drains constructed in natural drainages. During operations, surface inspections for erosion or soil stability would be performed on a quarterly basis. Additional discussion of slope stability at the WRF is provided in Section 3.3, Geohazards and Seismic Conditions.

Due to the potentially acid generating nature of PAG 6 category waste rock, it is to be kept as dry as possible and isolated from other waste rock. A low permeability overburden cap will be placed on each series of 100 foot lifts of PAG 6 material to minimize infiltration of surface waters. Prior to installation of each successive cap, PAG 6 material (cells) may require placement of a finer layer of waste rock up to 3.3 feet thick for leveling purposes and preventing the capping materials from settling into the underlying waste rock layer. Each cap would consist of engineered lifts of natural colluvium or terrace gravels yielding a 3.3-foot thick cap layer that is more conditionally resilient (e.g., frictional strength) in comparison to synthetic materials evaluated. In-situ testing of proposed cap source materials resulted in a hydraulic conductivity of approximately 4×10^{-9} cm/s, thus considered a suitable PAG cap with appropriate moisture content and compaction. Field trials and a quality assurance/control program would be required during waste dump construction to confirm a hydraulic conductivity is achieved within an order of magnitude described above (BGC 2011b).

- *TSF:* The North and South FWDDs would be removed during the third year of operation. Their dam footprints would be removed, re-graded, and BMPs utilized for erosion and stormwater control as appropriate. TSF surface conditions would also be monitored quarterly and weekly throughout mine operation.
- *Plant Site:* Surface water runoff derived from the plant site during operations would be considered contact water and managed in the Lower CWD. The surface water and any entrained sediment would be diverted to the TSF via culverts to avoid comingling runoff streams with TSF diversion channels.
- *Stockpiles:* Although the berm at the ore stockpile would not be necessary when the pits are developed, the berm would remain in place throughout operations to minimize runoff to the ACMA pit. The overburden stockpiles would be progressively reclaimed as practicable throughout operations to minimize erosion, surface entrainment, and infiltration.

Closure, Reclamation, and Monitoring

The mine site would be reclaimed to pre-mine erosion conditions to the extent practicable under the Reclamation and Closure Plan and ADNR reclamation requirements (SRK 2012f). Soil erosion is likely to occur during the closure and reclamation phase due to intrusive reclamation activities (i.e., heavy equipment) required to meet post-reclamation land use objectives, and sensitivities associated with newly reclaimed surfaces until stabilization is achieved. Large scale redistribution of topsoil would result in temporary destabilization of ground surfaces during mine site reclamation that would likely last for several years beyond closure.

Similar to the construction period, the potential for both hydraulic and wind erosion during closure would be greatest during non-winter months. The intensity of effects during non-winter construction are anticipated to be medium to high due to major earthworks and erosion inspection/maintenance tasks required for major mine site components (i.e., WRF, dam sites, TSF, infrastructure) before complete stabilization is achieved. However, effects are anticipated to be reduced to low to medium levels through proposed design features and BMPs.

Reclaimed components would be designed to withstand storm events (e.g., 100-year, 24-hour event) to maintain long-term stability, in addition to evaluation of select components in

response to changing conditions (Chapter 4, Cumulative Effects). Ongoing reclamation activities would be monitored on a routine basis (weekly or other). Additional inspections would also be performed following major rainstorm events, and corrective actions implemented as necessary to stabilize reclaimed surfaces. Reclaimed surfaces would be monitored annually for 5 years, or until stable revegetated conditions are reached. Application of growth media on disturbed surfaces would vary on a case-by-case basis, but would generally include placement of a 6-inch lift. Growth media would be tilled, roughened, and/or compacted to increase water retention, minimize erosion, and facilitate revegetation. Mulched materials would be added on an as-needed basis to facilitate germination processes and minimize erosion. Additional revegetation details and reclamation performance criteria are evaluated in Section 3.10, Vegetation.

Considerable earthwork (slope contouring and grading) would be performed at major mine site components during reclamation. Areas would include WRF, TSF, freshwater and process ponds, and select pit areas. Slopes would generally be finished at 3H:1V slopes. Specific design features and reclamation ESC measures for major mine components to control sediment and erosion would include the following.

- **WRF:** Closure of isolated PAG category waste rock areas would involve more specific cap material specifications as described in WRF Operations. Inactive/dormant slopes of the WRF during operation would be regraded and contoured, and compacted to a 3H:1V slope ratio to promote runoff and minimize surface water ponding and subsequent infiltration. Interim reclaimed surfaces would be covered in a 1-foot lift of overburden, followed by placement of a 1.15-foot thick mixture of fine-grained materials with organics to establish vegetative cover during operation. Surface completions would include ripping, scarification, and seed distribution and mulching as necessary. Brush or earthen berms would be constructed on toeslopes as erosion control measures until vegetative communities are established. The Lower CWD would be breached, liner and fill removed, re-graded, and surface reclaimed to a natural state. The liner would also be removed from the Upper CWD and backfilled with waste rock. Completed WRF surfaces would be graded to drain to a series of surface water drainage channels. All channelized surface water run-off and seepage would be collected and discharged to the ACMA pit. During the closure period, erosional stability evaluations would be performed quarterly for the first 5 years; annually the next 5 years, and once every 5 years thereafter.
- **TSF:** TSF dam faces would be covered during closure activities; slopes reduced from a 1.7H:1V slope to a 3H:1V slope for erosional stability; and surfaces would be covered by growth medium. The TSF cover would include 3.3 feet of coarse inert waste rock (non-ML/ARD), 1 foot of colluvium/terrace gravel, and completed with 1.15-foot thick peat/mineral growth media mixture to reduce infiltration. All surface water (cover) runoff would be directed to the southeast corner of the TSF; collected in a lined pond, tested, and discharged. Initial surface water discharge would be to the pit lake, but is anticipated to be suitable for discharge to Crevice Creek in Year 6 of TSF closure.

The TSF cover layers are not intended to completely prevent infiltration, but to control erosion and direct infiltration towards the rockfill layer, where it would be captured along with porewater squeezed out of the tailings in the early closure/consolidation period. Limited surface water infiltration through cap materials and expelled porewater

through Year 52 of TSF settlement would be captured in a series of manhole drains installed in the underlying layer of inert waste rock. The hydraulic conductivity of the TSF cover layers is expected to be on the order of 10^{-4} for the waste rock, 10^{-5} cm/s for the colluvium/gravel layer, and 10^{-4} to 10^{-3} cm/s for the peat mixture (BGC 2011a; Meiers et al. 2006; Rodger 2008). Infiltration would primarily be limited by the colluvium/gravel layer and the tailings themselves, which are estimated to have a hydraulic conductivity of roughly 10^{-6} to 10^{-5} cm/s (BGC 2011a). The waste rock layer would provide a capillary break between the cover materials, and also reduce salt mobilization into the upper growth medium. Collected water would be discharged to the ACMA Pit until TSF terminal density is reached by approximately year 52 of closure. No pumping would be required after terminal consolidation is reached. Additional discussion of TSF water volumes and water quality in closure is provided in Section 3.5, Surface Water Hydrology, and Section 3.7, Water Quality.

- *Mine Site Facilities:* Foundations would be broken up and reduced to rubble to facilitate infiltration. All buried debris would be covered with a minimum of 3.3 feet of gravel/colluvium. Footprints would be ripped, graded, re-contoured, and seeded. Growth medium would be spread on an as-needed basis. Yard areas and other large undefined disturbances would be reclaimed using methods similar to the WRF. The solid waste landfill surface cover and monitoring would be managed per applicable waste permit criteria.
- *Mine Site Roads:* Mine roads no longer required for post-closure monitoring and maintenance would be reclaimed using similar methods to mine site facilities. Reclamation of roadbed surfaces would include grading, ripping, and contouring of road bed and ditch surfaces to blend with existing landscapes. Asphalt road surfaces (where present) would be removed and buried in ditches and road depressions prior to grading and final reclamation. Seed would be sidecast following placement of growth media. A stream bank stabilization protocol would be developed to protect banks soils during reclamation at water body crossings that would incorporate guidance published in the State of Alaska (e.g., Walter et al. 2005).
- *Snow Gulch Reservoir:* This freshwater reservoir would be reclaimed during closure, including draining the reservoir and removing the dam. The dam footprint would be recontoured and revegetated. All power lines and pipelines would be decommissioned and reservoir access reclaimed. General reclamation procedures at closure include, but are not limited to earthwork activities at freshwater ponds. Inundation areas potentially most affected after dam closure (draining) would be located at elevations along the impoundment perimeter that correspond with the most frequent zone of water and ice fluctuation throughout operation (e.g., wave action, ice, etc.). Since water levels would commonly exist at a maximum storage elevation unless there is a contingent need for supplemental process water, this would potentially result in a limited acreage of stripped or affected soils along the impoundment perimeter at closure.

Summary of Mine Site Impacts

Planned erosion control mitigation at the mine site during construction, operation, and closure of Alternative 2 is expected to result in effective erosion control and reduction of intensity levels to low to medium based on standard and site-specific BMPs incorporated into project design

and monitoring/maintenance programs. The duration of effects would range from temporary to long-term, with impacts potentially lasting for months or years until stabilization of ESC measures is achieved or revegetation criteria are met (effects reduced to low intensity). The geographic extent of erosion effects would be local, in that impacts are expected to be limited to the immediate vicinity of the mine site footprints and stay within project property boundaries. Erosion effects are considered common to important in context, since affected soil resources have similar properties in the region; but some erosion scenarios could involve in resource hazards governed by regulation (e.g., cover material/containment, natural hazards).

Transportation Facilities

Compliance with erosion mitigation, control, and monitoring measures at transportation facilities would be addressed in a SWPPP Plan and related documents to be developed during final design (Appendix F). The current Donlin Gold *Plan of Operations* (SRK 2012a) does not provide specific ESC details for the proposed transportation infrastructure components of the project, although it is reasonable to assume for the purposes of evaluating effects, that such plans would be developed during permitting and be in place prior to construction.

Construction

Descriptions of potential or anticipated soil erosion scenarios during construction are provided below for the various transportation facility components. As described above under Mine Site, erosion effects are considered common to important in context, in that they impact common soil and water resources, but are also natural hazards governed by regulation. The duration of most erosion effects that are initiated during construction would be temporary to long-term, with impacts typically resolved within the span of the construction period or lasting for several years beyond it.

Mine Access Road, Airstrip, and Angyaruaq (Jungjuk) Port: Soil conditions along the proposed mine access road, airstrip, and port site range from slight to severe for both water-induced and wind erosion (Table 3.2-3 and Figure 3.2-1). Those rated severe for wind erosion are associated with loess soils and silty floodplains. Soil types and locations considered most susceptible to hydraulic erosion include colluvium and loess on slopes, localized areas of ice-rich soils, soils at water body crossings, and higher gradient slopes and sidehill cuts (up to 7.5 percent grade). Planned water body crossings, locations, and types are addressed in Section 2.3 (Chapter 2, Alternatives).

Because a large portion of the most invasive period of predevelopment and initial construction of the road would occur during winter months, minimal erosion is anticipated due to frozen conditions. The greatest potential for erosion would likely occur during periods of thaw during spring breakup or from summer rainfall and runoff events. Anticipated erosion during construction would primarily be attributed to hydraulic processes, and to a lesser extent wind processes. Thermal erosion (permafrost degradation) would contribute to hydraulic erosion processes where frozen soil conditions exist and discrete segments of the access road and the port site (Section 3.2.3.2.2). Construction activities and conditions that would potentially create or contribute to soil erosion along the road include:

- Removal and clearing of vegetation during development of the road bed, road bed ROW, and port site;

- Vegetative mat removal and overburden clearing for suitable substrate placement (cut and/or fill construction);
- Stockpile management of removed overburden and dredged materials, including high moisture content materials (ice-rich soils and dredge spoils) at the port site;
- Development of material sites and construction of access roads; and
- Equipment staging/storage areas.

Thus, the intensity of erosion effects during construction would be considered medium to high if uncontrolled, based on anticipated disturbances to a variety of surface conditions required during initial construction. While the degree of cut and fill along the road would largely depend on site-specific physical conditions (substrate materials and permafrost), minimum fill depths ranging from about 3 to 5 feet would help control erosion of exposed native soils in cuts. Culverts would be installed to control runoff and erosion at drainage crossings (Section 3.5, Surface Water Hydrology). Other than fill and culverts, current Donlin Gold plans do not provide specific ESC details or stabilization measures for the road and materials sites; however, a required SWPPP and discharge permit would also address erosion monitoring and mitigation.

Material site development and reclamation practices would vary based on physical conditions and material competency specific to each borrow site location. With the exception of MS10, material sites along the mine access road are in upland bedrock areas. BMPs employed during construction and operations to minimize erosion at these sites would include catch benches, slope angles appropriate to the competency of the material, controlled drainage, and overburden storage within site limits. At MS10, shallow pits would be developed in a raised alluvial plain between two tributaries of Getmuna Creek, and extend below the groundwater table. The pits would be separated from the creeks by distances ranging from 250 to 1,000 feet (Recon 2011c).

Material site reclamation would typically follow after no further material quantities are needed. Since some material sites would be re-purposed to serve other project needs (e.g., project man camp, staging area, etc.), reclamation at these sites may not occur until mine closure. Anticipated material site reclamation practices would include the following (Recon 2011c):

- Redirecting surface water drainage to naturally vegetated slopes or other engineered receptors (e.g., ditches, collection swales) during operation and final reclamation;
- Re-contouring unconsolidated soil slopes to a maximum 2:1 grade, and a minimum 1 percent grade. In some circumstances, soil slopes would be reduced to a maximum 3:1 grade;
- All loose soil slopes would be compacted (tracked) followed by placement of fertilizer and seed on a case-by-case basis;
- Compacted areas would be ripped and graded to conform with surrounding topography, and scarified for revegetation;
- Overburden would be distributed over pit floors, slopes, and other areas deemed most appropriate. This may include preferential use of overburden for material site access road reclamation where overburden availability is limited. Under these circumstances, some portions of the pit floor may be left as developed;
- Overburden would be spread over access roads, followed by tracking and seeding;

- Competent bedrock slopes would be left in benched configurations as developed during the mining process. Catch benches would extend 10 feet outward every 20 vertical feet of quarry wall and overall slopes will typically range from 1:1 to 1.5:1 slope angles. Weathered or highly fractured bedrock will typically be finished with 2:1 slope angles;
- Soil and gravel slopes above waterline at material sites extending below the water table (e.g., MS10) would be reduced to a 3:1 slope around each pond, and an undulating shoreline would be engineered at each pond using overburden materials. There are no current plans to connect the ponds to nearby creeks. All surfaces would be tracked and seeded for erosion control as necessary, or allowed to re-vegetate with local shrubs and grasses followed by tracking.

Overburden removal during grading and construction of the airstrip would be placed in two overburden dumps at either end of the airstrip (Figure 2.3-13). Soils at this site are composed of silty loess overlying weathered sandstone bedrock (with no permafrost) (BGC 2013h), which could be susceptible to erosion. While ESC measures and BMPs have not been specified for the airstrip dumps, these are typically addressed in final design as part of SWPPP permitting. As such, impacts such as runoff toward the creeks on either side of the airstrip, which are tributaries to northwest-flowing Montana Creek, are expected to be minimized to a low level of intensity through SWPPP requirements.

Approximately 10,000 cy of dredged materials derived from port construction would be placed in the 5-acre overburden stockpile at the port site. The stockpile would be situated on relatively level thaw-stable ground on the upland side of the port away from waterbodies and wetlands, and constructed with low sloping profiles. While other ESC design features specific to thawing permafrost soils (such as a sediment pond) have not been defined yet for the stockpile, it is reasonable to assume that this would be addressed in final design as part of SWPPP permitting, and the likelihood that sediment-laden runoff would flow towards the Kuskokwim River is considered low. Thus, ESC features at the airstrip dumps and port stockpile are expected to be effective in managing erosion impacts at low intensity levels.

Kuskokwim River Corridor: Soils comprising bank material along the Kuskokwim River corridor could potentially be disturbed through hydraulic erosional processes derived from wave-induced, project barge traffic. These processes and associated impacts are presented in Section 3.5, Surface Water Hydrology. The level of effects from potential erosion at relay points would be the same as described in Section 3.2.3.2.1 (Soil Disturbances/Removal).

Bethel Port: Based on the fine-grained characteristics of surface materials (loam) at the Bethel Port, the potential for erosion exists during construction. However, site conditions are considered less conducive for erosional processes (hydraulic), as the local topography is predominantly level and the soils are well drained to moderately well drained. Potential erosion along higher gradient areas of the Kuskokwim River shoreline is expected to be mitigated by construction of a permanent sheetpile retaining wall in this area (Section 3.2.3.2.1). No maintenance dredging or uplands disposal of dredge material is currently proposed for the Bethel Port based on planned improvements to dock design and depth (Fernandez 2014b). Thus the intensity of erosion effects is generally considered low for this site.

Dutch Harbor Port Expansion: Unconsolidated materials over shallow bedrock at the Dutch Harbor Port could potentially become unstable during periods of heavy precipitation, particularly on steep slopes (if any). Surfaces would be most susceptible to erosion during

construction when surfaces are disturbed. Effects would be local, limited to the immediate vicinity of the disturbed area (4 to 6 acres), and the period of construction would likely be limited to 1 year or less. Initial cargo and/or fueling infrastructure upgrade activities by a third-party contractor would likely include excavation and bedding material placement (as necessary). Because construction activities would likely occur at an existing facility, the third party would either modify an existing SWPPP for the facility that would address BMPs and ESC measures, or generate a project stand-alone SWPPP for regulatory review. It is also possible that the required expansion upgrades would occur in previously disturbed areas, and where ESC measures already exist or partially exist. Thus, the intensity of erosion effects at the Dutch Harbor Port is considered low to medium, in that erosion could occur, but existing or new ESC measures are expected to be effective in controlling it. Stabilization of surfaces with respect to erosion would likely occur during or immediately after the construction phase.

Operations and Maintenance

Erosion derived from the proposed transportation facilities throughout operations would primarily be attributed to the mine access road, and to a lesser extent, the Angyaruaq (Jungjuk) and Bethel Port facilities. The intensity of erosion effects along the road during operations would likely be low to medium, based on planned design features (e.g., culverts) and SWPPP monitoring/maintenance requirements. Although post-construction stabilization and restoration measures would address most immediate erosion concerns along the road, continued maintenance would be required over the indefinite life span of the road per the SWPPP. Visual inspections would be continuously performed throughout operation based on traffic reports and pre-determined inspection intervals. Ongoing soil stabilization and restoration measures would likely be required locally at high gradient slopes or side cuts, fine-grained soils, thermally unstable ice-rich soil, water body crossings, and wetlands.

Erosion at the port sites during operation would likely be minimal based on the comparatively small footprints, planned design features (e.g., Bethel shoreline fortification), and ongoing SWPPP monitoring/maintenance requirements. The most important incremental source of erosion during operations would be from minor maintenance dredge material from the Angyaruaq (Jungjuk) Port berth being placed in the uplands waste soil stockpile. These are expected to cause ongoing effects similar to, but on a smaller scale as, those described under Construction.

Indirect erosion effects could occur from ORV access to areas off the mine access road during shoulder seasons if access via Angyaruaq (Jungjuk) Port is not controlled. Degradation might include increased erosion and soil displacement (gullyng, churning and rutting), compaction, damage to supporting vegetation and sustainability; changes to the surface water flow regime, and related permafrost degradation (Loomis and Lieberman 2006). These effects could range from low to medium intensity with localized areas of high intensity impacts in organic or ice-rich soils. The extent of effects could range from the immediate vicinity of the road to several 10s of miles from the road, but would be somewhat limited by terrain and trafficability.

Closure, Reclamation, and Monitoring

The mine access road would remain in an operational state indefinitely throughout mine site reclamation and post-closure to support long term monitoring and WTP operation. Effects would be the same as described above under Operations, and would require continued

monitoring and maintenance (as needed) per SWPPP requirements, and access restrictions for ORV use, if adopted. Monitoring and maintenance details for the road in post-closure are not detailed in the Donlin Gold *Monitoring Plan*, but are expected to be addressed during final reclamation and closure planning.

A key source of potential erosion during closure would include reclamation (removal) of Angyaruaq (Jungjuk) Port shoreline infrastructure (i.e., moorage, approaches, sheetpile infrastructure, and associated fill). Surfaces would be graded, contoured, and revegetated as necessary for surface stabilization, and monitored until rehabilitation criteria are met, using similar practices described above for mine site closure (SRK 2012f). The intensity of erosion effects would be low to medium, as impacts are expected to be minimized through BMPs in SWPPP requirements and proposed reclamation practices. Post-reclamation monitoring (or corrective actions) would coincide with other scheduled mine site closure activities described in planning documents for reclamation performance standard compliance (Appendix F).

The Bethel and Dutch Harbor facilities would likely continue to operate in the closure period. As such, impacts from erosion would be the same as described for Operations and Maintenance.

Summary of Transportation Facilities Impacts

Erosion effects at the various transportation infrastructure components during construction, operation, and closure of Alternative 2 are expected to would mostly range from low to medium intensity (e.g., at road cuts, or during port reclamation activities), assuming that required SWPPP and discharge permits address specific transportation facilities, although indirect effects from seasonal ORV usage along the mine access road could lead to occasional high intensity erosion effects. The duration of most erosion effects would range from temporary (e.g., several months for individual locations or events) to long-term (e.g., port reclamation or ORV effects potentially lasting for years until restabilized). The geographic extent of erosion effects would be mostly local, in that impacts are expected to be limited to the immediate vicinity of individual infrastructure footprints, although indirect effects from increased ORV access could potentially extend beyond the project vicinity. Erosion effects are considered common to important in context, in that they impact common soil and water resources, but are also natural hazards governed by regulation.

Natural Gas Pipeline

The following discussion addresses potential impacts along the proposed pipeline from hydraulic (water) and wind erosion. Interdependent relationships between hydraulic and thermal erosion processes (permafrost degradation) are addressed in Section 3.2.3.2.2.

Proposed erosion mitigation measures contained in the preliminary ESCP (SRK 2013b) would be required with each phase of the proposed pipeline project (construction, operation, and closure) to achieve eventual stabilization and reclamation criteria. Separate SWPPP, O&M, and SRR plans would be developed to address erosion controls related to stormwater runoff, erosion maintenance during operations and reclamation activities, and surety costs upon pipeline closure and termination.). Specific references to these documents are provided below as applicable to soil erosion impacts along the pipeline.

Construction

The proposed pipeline alignment traverses a variety of different soil types for which NRCS and STATSGO erosion criteria are available (Table 3.2-1, Table 3.2-7, Table 3.2-8, and Figure 3.2-6 through Figure 3.2-8). Water and wind erosion descriptions for soil types along the pipeline range from “not applicable” (e.g., poorly drained peat) to severe based on available information. Although multiple major soil components (shallow) associated with the central pipeline segment have erosion factors (K_w) greater than 0.4 (Table 3.2-8), values are predominantly less than 0.4.

Due to the variety of erosional susceptibilities and landform terrains traversed by pipeline, the potential for erosion exists along multiple segments of the 315-mile route. Much of the pipeline ROW and ancillary components are associated with soil map units having moderate to severe erosion potential from both water and wind (with the organic mat removed). Erosional effects from wind would likely be less intense due to concurrent surface stabilization/reclamation efforts and physical environmental conditions associated with the Project Area. Physical conditions that would influence erosional processes include seasonal construction methods and associated surface disturbances (e.g., vegetation removal, compaction), slope gradient, soil moisture content, and alteration of surface water drainage patterns. In general, soils exposed during construction would be more susceptible to both hydraulic and wind erosion than soils with the organic mat left intact, partially intact, or compacted. This is particularly the case for fine-grained materials on steep exposed slopes.

A variety of construction activities could contribute to erosion, including on- and off-ROW clearing and grading; excavation trenching, stockpile management, and backfilling; multiple water body and wetland crossings; and development of gravel pads for certain ROW conditions and off-ROW facilities. Without mitigation, erosion from runoff and other hydraulic processes could result in adverse impacts to native or engineered soils and to downgradient sensitive areas (e.g., water bodies, wetlands). Most erosion effects are anticipated to be of low to medium intensity, however, in that they are expected to be managed effectively through ESC measures. It is possible that isolated occurrences of high magnitude (i.e., uncontrolled) erosion could occur that are not immediately contained by the BMPs described below. These cases would likely be reduced to medium intensity (i.e., controlled) within a short period of time, due to planned redundancies in ESC measures and reclamation/cleanup crew functions at the end of the construction period. The duration of most impacts would range from temporary (due to planned BMPs and reclamation measures immediately following construction of each pipeline segment) to long-term (for effects in more susceptible areas that last for several years beyond construction).

Specific construction activities that could cause erosion effects, as well as proposed ESC measures and BMPs that would mitigate these effects (SRK 2013b), are described below for both ROW and off-ROW pipeline components.

Pipeline ROW

Season of Construction: Approximately 68 percent of pipeline length would be constructed during frozen winter conditions to accommodate support equipment and minimize soil erosion. Temporary erosion control measures are not anticipated during winter construction that is planned to occur over two winter seasons. Areas planned for summer or fall construction are based on favorable geotechnical and terrain conditions, such as stable permafrost and/or

suitable surface soils that would support equipment (e.g., gravel floodplains, shallow bedrock), and work length continuity considerations. Steep terrain and side slopes are also preferred for summer construction due to safety considerations for equipment operation.

Temporary ESC Measures – Summer Construction: Temporary stabilization and erosion controls would be installed in areas of summer construction as soon as practicable in the construction sequence in order to contain disturbed soils. Application of temporary stabilization controls would be addressed in the SWPPP and ESCP. Specific controls and measures used in summer construction areas would include:

- Minimization of areas of compacted vegetation, disturbance of natural waters, and existing drainage patterns where practicable;
- Salvaging organic mats above cuts for use as surface replacement material;
- Ripping/scarifying compacted areas and soil roughening using tracked machinery that would traverse slope fall lines to reduce surface water runoff and facilitate infiltration and revegetation;
- Installation of settlement basins;
- Filter bag use for dewatering discharge treatment;
- Installation of brush berms orientated perpendicular to surface water flow and keyed into surface soils;
- Installation of silt fences constructed of geofabric and trenched (keyed) or anchored to surfaces to intercept offsite migration of eroded sediment;
- Installation of silt curtains in placid or low-flowing water bodies adjacent to disturbed areas, that act as turbidity barriers to prevent dispersion of sediment-laden water;
- Finished slope angles designed to maximize stability and minimize erosion relative to soil types and hydrologic conditions;
- Engineered flow diversion over cut or fill slopes where appropriate, including installation of drainage levees and other structures to minimize ponding adjacent to embankments;
- Installation of slope breakers (water bars) constructed of native soil and orientated across slope or perpendicular to surface water flow to decrease runoff velocity and divert water into energy dissipaters or well established vegetation. Slope breakers would be installed at predetermined intervals based on slope gradient conditions;
- Installation of temporary and permanent trench breakers. Temporary trench breakers would be installed during construction to control sediment laden water movement in the trench. Permanent breakers would be installed in sloping terrain to address preferential groundwater flow through trench backfill that may result in subsurface erosion or backfill alteration;
- Installation of surface protection controls, such as wattles or RECPs, which are stapled together and pinned down over uniform surfaces and slope breakers, or positioned perpendicular to the anticipated direction of runoff. The base of installed RECPs and wattles would be anchored or keyed into soils. Installation of chipped or shredded mulch derived from ROW clearing that would be applied at a uniform thickness of 1.5 tons per acre; and
- Watering of high traffic surfaces as needed for dust control using water trucks.

Trench and ROW Completion: Trench backfilling would be completed with a mounded (crowned) surface completion to accommodate settlement, and prevent ponding or surface water channelization. Finish grading in the ROW would direct surface water away from the pipeline, and water bars would be constructed on steep longitudinal slopes for drainage control and erosion mitigation. The ROW would be cleared of construction debris, and workpad surfaces graded and scarified to promote natural revegetation at suitable locations. Suitable locations selected for natural vegetation would have adequate natural seed sources or rootstock, and a low potential for erosion.

General BMPs – Revegetation: Vegetation disturbances could influence soil erosion through increased surface water runoff velocities, channelization or ponding (erosion), and potential thermal degradation of permafrost conditions (if any). Major vegetation removal would occur within the construction ROW to develop the work pad and trench line. For these reasons, areas of vegetation affected directly or indirectly by the proposed pipeline would be identified and corrected per the approved SRR Plan, other applicable plans and regulatory requirements (e.g., APDES permit and SWPP, ESCP), or as agreed upon with land owners outside the construction area as applicable. Corrective actions would include identification and documentation of the disturbance; rehabilitation and reclamation; and continued monitoring. Restoration measures would include distribution of slash and chipped vegetation within the ROW to facilitate erosion control and seeding and fertilization. Tree trunks used for corduroy road bed materials (where applicable) would be left in place on the workpad surface. Additional measures applicable to vegetation/reclamation management are described in Section 3.11, Wetlands.

General BMPs – Slopes: Planned slope cuts may result in soil instability. Key considerations include slope grade (topography), soil cohesion, and permafrost stability (where present). Both temporary and permanent ESC measures are anticipated for most slope cut activities; however, winter construction would reduce the need for temporary measures. Of primary concern is the erosion potential (energy) associated with higher velocity surface water flows on inclined surfaces, including flow channelization along the trenchline, within the trench, and destabilization (erosion and settlement) of surface soils and trench backfill materials. The following ESC measures would be based on final design and onsite evaluation during construction:

- Slope breakers would be used at predetermined intervals based on slope gradient criteria, and would divert water and sediment to stable vegetation or energy dissipaters;
- Permanent breakers would be installed in sloping terrain to address preferential groundwater flow through trench backfill that may result in erosion or backfill alteration;
- Fiber/geotextile or erosion mats would serve as both temporary or permanent ESC measures until vegetation is reestablished;
- Silt fencing and wattles would be installed for sediment retention control until stable conditions are achieved; and
- Completed slopes would be roughened and mulch installed to facilitate water infiltration, surface stabilization, and provide surface cover for regrowth of vegetation. If necessary, slopes would be seeded as soon as practicable.

Temporary Soil Stockpiles: Most material excavated during pipeline trenching would be used as backfill material or surface completion material during final grading and contouring. This would require temporary stockpiling of segregated materials based on intended salvage use. Stockpile location and design considerations would include seasonal conditions (rain, wind, meltwater, etc.), terrain (slope and vegetation), and material type (organics, permafrost, ground ice). Management of stockpiles would incorporate the following:

- Stockpiles would be situated sufficiently far from potential receptors or sensitive areas such as waterbodies or wetlands;
- Stockpiles would be constructed with low sloping profiles and roughened to minimize soil erosion;
- Silt fencing and wattles would be placed around inactive stockpiles; and
- Stockpiles would be covered with plastic if there is an increased risk of runoff to the surrounding area, or high-risk weather conditions. (Additional considerations for ice-rich stockpiles are provided in Section 3.2.3.2.2).

Water Approach Stockpiles: Most methods of construction associated with water body crossings could result in temporary stockpiling of excavated materials. Stockpile management at these locations would include:

- Excavated spoils would be segregated based on source materials (terrestrial vs. water body);
- Stockpiles would be situated a minimum set back distance of 30 feet from receiving water bodies;
- Erosion containment measures would be placed around the sides of the stockpile, in addition to the front edge upslope of the receiving water body; and
- Silt curtains would be installed along the bank as temporary turbidity barriers.

Additional measures applicable to fish and aquatic resource occurrence and management are described in Section 3.13, Fish and Aquatic Resources.

Snow Stockpiles: Snow clearing and management would be conducted as necessary during construction to allow for safe equipment operation. Stockpiles would be designed for snow storage, and would incorporate water diversion ditches to control meltwater drainage to well established vegetation or dissipaters. All discharge would comply with approved pipeline project permits.

HDD Sites: Soil impacts associated with HDD work areas include disturbances to existing conditions from heavy equipment excavation, drilling, and support equipment operation. HDD work sites would be set back from the riverbanks in distances ranging from 400 to 3,900 feet, and delineated to minimize soil disturbance impacts while accommodating operational efficiency and safety. Visual inspection would be conducted throughout drilling to verify drilling mud management and ESC measures. Silt fences, straw bales, or wattles would be placed around stockpiled spoils generated for drill entry and exit. All excess drilling mud would be removed from the site, and disposed of as required in relevant regulations and permit stipulations.

Cleanup and Reclamation Crews: Designated crews would address both cleanup and reclamation activities following pipeline installation and backfilling. Cleanup crews would perform all cleanup activities during the same summer or winter pipeline installation season. Reclamation crews would immediately follow cleanup crews during summer installation or the next shoulder season following winter work. Cleanup crew activities would occur immediately after trench backfilling. The cleanup crew would be responsible for finish grading and surface completion activities, including:

- Removal of temporary bridges, culverts, tools, materials, support equipment, and trash from the ROW;
- Reconnaissance for any contaminated soil conditions, and addressing if necessary by treatment and/or removal from the Project Area for proper disposal;
- Grading of spilled bedding/padding material or gravel over ice, snow, or frost-packed work pads for traction, or placement over the trench line;
- Crowning of the pipeline trench mound using salvaged organic materials or suitable fine-grained materials for revegetation;
- Excavation or cutting breaks in the mounded trench surface to allow cross drainage along the ROW, and prevent ponding or surface water channelization. Breaks would be installed at all known cross-drainages and trench breaker locations. Generous use of breaks would be placed along cross slopes and permafrost terrain;
- Placement of permanent slope breakers that span disturbed surfaces (trench or work side of the ROW), and at trench breaker locations;
- Removal of all ice or snow in drainages and ice bridges on ice/snow pads and frost-packed ROW areas;
- Re-contouring of cuts to match local topography as practicable, placement of salvaged organic material on restored cuts, and restoration of stream banks to original configuration (additional considerations for cuts and stream banks in permafrost are addressed in Section 3.2.3.2.2);
- Installation of permanent erosion control measures/materials on high gradient slopes in close proximity to sensitive areas (e.g., streams); and
- Installation of signage pertinent to controlling access to minimize erosion.

Initial tasks performed by reclamation crews would include identification and prioritization of deficient or compromised areas. A more methodical and comprehensive reclamation process would occur once high priority issues have been addressed. Reclamation crews would access these areas via helicopter, walking, or low ground pressure carriers. Final inspection of erosion control measures would be performed at the end of the season, and any remaining or developed erosion and settlement issues would be repaired. Specific functions of reclamation crews would include:

- Removal of all excess tools, materials, and trash missed by cleanup crews;
- Installation of additional breaks in crowned trench surface completions as needed, and addressing any settlement occurrences;

- Installation of additional slope breakers as needed;
- Inspection of stream banks for erosion; and
- Revegetation of disturbed areas using seed, fertilizer, and mulch as required.

Off-ROW Facilities

Transmission Line: Specific BMPs and ESC measures associated with transmission line construction include the following:

- Cleared vegetation from the ROW would be mulched and spread for erosion control;
- Soil cuttings generated from drilling activities (augering) would be consolidated into managed stockpiles or used for construction purposes; and
- Wattles, silt fences, and/or straw bales would be placed around drill sites for soil containment, and would remain in place around the poured concrete support members until final stabilization.

Temporary Summer or All-Season Access Roads: Temporary access and shoofly roads intended for summer or all-season use would be graded or constructed of gravel. Gravel fill construction would help to minimize erosion of native soils. Grading activities could cause airborne dust along access roads and high construction areas in summer, and watering would be performed on an as-needed basis. Other ESC design features such as culverts, drainage ditches, or cut slope BMPs have not been specified for these roads, although these features are expected to be detailed in the final SWPPP and ESCP for the pipeline.

Winter Access Roads: Ice access roads, winter shoofly roads, and other temporary roads used to access the ROW in winter construction sections would serve to protect native soils and wetlands. Construction of the 3-year, 46- to 50-mile long winter access road along either the Oilwell Road or Willow Landing routes would include the following elements pertinent to erosion control:

- Routes have been selected to avoid high relief topography; minimize clearing; maximize use of disturbed areas (existing roads, trails, historic stream crossings) and low relief open marshy areas that freeze readily; and minimize stream bank disturbance in developing adequate crossings for heavy equipment and loads;
- Road clearing/mulching would be conducted the winter before pipeline construction using tracked or rubber-tired vehicles. Mulch and organic debris from clearing would be left on the ground surface;
- Limited cut and fill would be required in areas where sloughing has occurred and grades are too steep for intended use;
- Road surface hardening and ice buildup at stream crossing would be accomplished by buildup of clean snow and pumping water onto the surface from significant flowing streams; and
- Road maintenance would occur in winter by packing, watering, and grading the snow/ice surface.

Camps and Storage Yards: Specific BMPs and ESC measures associated with construction camp and storage yard construction include the following:

- Areas of soil disturbance would be minimized to the extent practicable to accommodate camp, storage, and work area needs;
- Surface vegetation would be removed and infrastructure/equipment would be built or placed on stable gravel pads or temporary construction mats;
- Temporary diversion ditches along the yard/camp perimeters would be used to direct discharge to well established vegetation or flow dissipaters (rock);
- Silt fences and/or wattles would be placed along the outer edges of diversion ditches to intercept offsite erosion by sediment capture;
- Access and egress points would be minimally sized to accommodate safe movement of personnel and equipment, and coarse gravel placed as needed to reduce sediment tracking from access points; and
- Dust control in high traffic areas would be performed through surface watering on an as-needed basis.

Material Sites: Gravel and bedrock borrow pits would be sited to avoid environmentally sensitive areas, and would generally incorporate the same ESC measures described above for temporary soil stockpiles. Material would only be excavated on an as-needed basis to minimize areas of disturbance and associated potential for erosion. Anticipated pipeline material site development and reclamation practices would also include those described for Transportation Facilities material sites (Section 3.2.3.2.3).

Airstrips: To the extent practicable, low erodibility aggregate would be used for fill at airstrips, resulting in a low potential for erosion by wind and water. Surface watering would be performed on an as-needed basis for dust control.

Valves, Pig, and Metering Stations: No ESC measures are anticipated for construction of these small facilities; however, this would be reevaluated during pipeline construction and implemented as needed.

Cleanup and Reclamation: Ancillary facilities would be decommissioned as soon as possible within the construction period when no longer needed. Cleanup and reclamation of off-ROW facilities not needed in operations would be similar to that described above under Pipeline ROW. All structures, equipment, and debris would be removed, including contaminated soils (if any) based on visual reconnaissance. Gravel pads and fill at camps, storage yards, temporary airstrips, and access roads would be left in place and revegetated. Compacted areas would be ripped and graded to blend in with surrounding topography and facilitate drainage, and any high walls at material sites would be left in a stable condition. Surfaces would be scarified for natural revegetation, mulched, or fertilized and seeded as appropriate per the SRR Plan.

Operations and Maintenance

Ongoing Effects from Construction: Soil erosion during pipeline operations would primarily be associated with lingering effects associated with construction and post-construction reclamation, as new soil disturbances activities during operations would be limited (Section 3.2.3.2.1). Post-construction reclamation and ESC measures are anticipated to address most erosion concerns along the pipeline, and ESC measures would be maintained as needed until final stabilization criteria are met; however, ongoing soil stabilization and restoration measures are likely to be a multi-year process in discrete areas. The level of intensity of effects during

operations would be similar to that described under Construction, with low to medium intensity effects in most areas, and isolated spots of occasional temporary high intensity effects that require increased monitoring frequency and maintenance attention to reduce effects to medium intensity levels. Areas that would potentially require more intensive stabilization and restoration measures would include high gradient slopes or side cuts, fine-grained soils, thermally unstable ice-rich soil, water body crossings, and wetlands. The effects of hydraulic erosion processes are anticipated to be substantially greater than the effects of wind erosion over the design life of the pipeline due to more immediate vegetation restoration reducing wind erosion effects. Hydraulic erosion processes of concern include surface water channelization and formation of preferential flow pathways along slopes; ponding associated with thaw settlement (subsidence), and trench backfill destabilization through potential groundwater movement. The placement of salvaged organic-rich/fine-grained soils as mounded trench cap material in some areas could be susceptible to erosion on a temporary basis.

O&M Activities: Operation activities would include preventative and corrective maintenance per the O&M Plan/Manual (Appendix F). A minimum permanent ROW width would be cleared of vegetation at approximate 10-year intervals or as necessary to accommodate surveillance, monitoring, and inspection activities. Surveillance and inspections would be performed twice a year, with no inspection interval exceeding 9 months. Inspection and monitoring would be performed following major rainstorms and after spring breakup. Qualitative visual inspections would be performed periodically, and quantitative inspections would be performed once per year at the end of the growing season. Final stabilization of construction-related disturbances would be achieved when a uniform vegetation area of cover of 70 percent is established (i.e., evenly distributed, without large bare areas), or the area has equivalent non-vegetation or permanent stabilization measures in place (ADEC 2011a; EPA 2007). Erosion caused by the O&M activities themselves could occur along any length of the pipeline where follow up service is required. These activities would be performed according to the established O&M Plan/Manual and follow BMPs and directives outlined in the SRR and ESCPs.

Public Access/ORV Erosion: Long-term indirect erosion effects by recreation and ORV usage could occur along the pipeline ROW following construction. As described in Section 3.2.2.3.3 (Erosion – Processes), authorized or unauthorized use of ORVs could result in erosion and damage to the ROW, particularly in areas with permafrost, sloping terrain, and/or organic, wet, fine-grained soils, which could potentially affect existing ESC measures or create the need for additional ESC measures.

Construction of the pipeline ROW will also result in varying degrees of soil compaction through heavy equipment operation. Although compaction reduces the volume of soil, adverse effects are primarily addressed through existing soil resource criteria that include soil disturbances and productivity losses, and erosion through surface water channelization or ponded water. Key variables that influence these soil resources of concern include the type and frequency of ORV use, operator discretion, physical attributes of affected soils, and surrounding terrain (slope). Descriptions of surface material types, terrain, and surface organics for the pipeline corridor are presented in Appendix F.

Various aspects of soil mitigation, restoration, and reclamation measures described above and in Sections 3.2.3.2.2 and 3.2.3.2.3 would minimize the effects of soil compaction. A planned measure that addresses compaction following construction of the pipeline ROW and

reclamation of ancillary components is ripping/scarifying compacted areas and soil roughening using tracked machinery to reduce surface water runoff and facilitate infiltration and revegetation.

The pipeline ROW corridor could result in ORV usage following construction, increasing the potential for ORV induced soil compaction. It is reasonably expected that only discrete portions of the ROW will be used due to perceived access limitations, thus limiting soil impairment concerns. Public access to the ROW would generally be limited due to the following reasons:

- No new public vehicular access will be created by Donlin;
- Areas with favorable compaction for travel would be discontinuous based on soil conditions and seasonal construction schedules (winter versus summer);
- Obstacles to passage such as wetlands and water bodies would be restored to pre-construction conditions; and
- The area is remote area and more suitable seasonal means of transportation are available (snowmachines) that are more likely to be used to access larger extents of the ROW.

Remote pipeline ROW access points of concern include project related airstrips. With the exception of three existing airstrips (Beluga, Farewell, and Donlin) and isolated ancillary facilities (e.g., compressor station and ancillary facilities), all pipeline construction infrastructure that could be utilized for access (if left in place) would be reclaimed. Temporary airstrips would be decommissioned in a way to prevent future use. Although the pipeline ROW does not create an exclusive right of access by Donlin Gold, placement of large berms or other means to discourage ORV traffic along or across the ROW intersections at existing trails would be considered upon coordination with the appropriate landowners. Additional control measures to alleviate ORV effects may include public outreach/education, posted notices, signage, flagging, barricades, and retaining select ESC measures after construction (SRK 2013b).

It is likely that snow machine-induced erosion along the ROW would occur along the portion of the pipeline in the Matanuska-Susitna (Mat-Su) Borough from regular winter use in areas of wet organic soils on shoulder seasons or periods of thin snow. However, impacts imposed by ORV traffic would likely be most extensive in the vicinity of the existing Farewell Airstrip. The Farewell Airstrip is currently used by multiple recreational user groups, and coincides with the subsistence use area for the village of Nikolai (Section 3.21, Subsistence). The subsistence use area for the village of Nikolai generally extends from MP 150 to MP 175. Access to the pipeline ROW could be substantial through existing ORV trails, resulting in impaired portions of restored and reclaimed ROW areas, and creating access to new untouched areas off the ROW depending on terrain conditions.

Surface materials throughout this area commonly consist of silt sand mixtures overlain by organic materials (peat/muskeg) that are 0.5 to 1.5 feet thick. Gravel mixtures are common but less prevalent, and peat/muskeg thicknesses were documented at one location to reach depths up to 13 feet. Permafrost conditions are also frequently interspersed throughout this area, with notable spans of unstable permafrost segments. ROW landform slopes (longitudinal and cross) are intermittently steep from MP 150 to 154, but generally assume low gradient slope aspects thereafter to MP 175. Based on the probable increase in ORV traffic along this pipeline ROW span, the prevalence of sand and silt surface soils with organic cover, and unstable and stable permafrost conditions, the potential for ORV soil impairments may result in a medium to high intensity of disturbance that would affect discrete segments of the pipeline ROW. Impacts from

traffic (ORVs) could result in localized permanent impairments to a resource that is common in context throughout this locally affected area. Overall however, the intensity of effects from ORV use would be similar to that of lingering effects from construction described above due to likely impediments restricting ORV access (summer) to the pipeline ROW on a local basis. It is also possible that ORV impairments could be more geographically extensive (affecting larger areas of the ROW, and miles beyond the ROW depending on terrain conditions), as well as longer in duration, potentially lasting for the life of the Donlin Gold Project.

Closure, Reclamation, and Monitoring

Pipeline termination activities pertinent to soil erosion would be the same as those described in Section 3.2.3.2.1. In-place abandonment of all subsurface pipes would minimize post-closure work requiring heavy equipment; thus, the intensity of erosion effects along most of the ROW would be negligible. Soil erosion could occur where above-ground pipeline removal/demolition activities take place due to equipment support work and associated surface disturbances. Where applicable, closure activities would be performed from stabilized/restored work surfaces. As with the construction and operations period, ESC and SRR plans would be followed during termination to achieve eventual stabilization and reclamation criteria. Thus, the intensity and duration of effects at above-ground sites would be the same as those described above for post-construction reclamation and operations. The extent of effects is expected to be localized within the immediate vicinity of above-ground facility footprints. While the season of final pipeline termination/reclamation is not specified in the current pipeline *Plan of Development* (SRK 2013b), closure activities that occur during the winter season (similar to construction) would help to minimize surface disturbances to soil (Chapter 5, Impact Avoidance, Minimization, and Mitigation).

Summary of Natural Gas Pipeline Impacts

Erosion effects along the pipeline ROW and off-ROW facilities during construction, operation, and closure of Alternative 2 are anticipated to be mostly of low to medium intensity (i.e., managed effectively through ESC measures), with isolated occurrences of high intensity erosion (during ROW construction, or ORV use near discrete segments of ROW). Erosion during construction would likely be reduced to medium intensity within a short period of time due to planned redundancies in ESC measures, reclamation/cleanup crew functions, and monitoring/maintenance activities. Erosion effects from ORV use would be minimized by a number of impediments restricting access. The duration of most impacts would range from temporary (e.g., ESC measures effective immediately following construction) to long-term (e.g., effects in erosion-susceptible soils lasting for years). The geographic extent of erosion effects would be mostly local, in that impacts would be limited to the immediate vicinity of the ROW and off-ROW facility footprints, while indirect ORV erosion effects could be local to regional, potentially extending for miles beyond the ROW if used to access new areas. Erosion effects are considered common to important in context, in that they impact common soil and water resources, but are also natural hazards governed by regulation.

3.2.3.2.4 SOIL QUALITY/CONTAMINATED SITES

This section describes potential effects from existing contaminated soils, as well as the effects of project activities (such as fugitive dust) on soil chemical quality. Evaluation of impacts to soil

quality associated with potential project-related but unplanned and uncontrolled releases (such as diesel spills) are addressed in Section 3.24, Spill Risk.

A review of available information concerning the presence of existing contaminated sites was performed for the mine site, transportation facilities, and pipeline components (Sections 3.2.2.1.4, 3.2.2.2.4, and 3.2.2.3.4) to identify possible impacts to the project and from project activities due to the presence of contaminated soils. Common impacts associated with pre-existing contaminated site conditions typically include management of the environmental concern to accommodate stakeholder interests, including:

- Correspondence with appropriate state, federal, or local regulatory agencies, and relevant stakeholders;
- Contaminated media characterization, remediation, or implementation of appropriate management and/or mitigation measures (e.g., institutional controls);
- Compliance with appropriate state, federal, or local regulatory agencies, including planning, reporting, and decision documents.

If conditions are unknown in advance, effects could also include inadvertent spreading or migration of contaminants beyond their initial location in areas of intrusive project work (e.g. excavations), and possible delays in project construction.

There have been no reported or suspected adverse soil conditions involving hydrocarbons or cyanide from past or current project developments, and no effects from these constituents are planned as part of the proposed project. As noted in Section 3.2.2.1.4, no baseline data for hydrocarbons and cyanide have been collected at the mine site. If necessary, regulatory guidance specific to evaluation of background analyte concentrations in soil could be used in the event of a future release (described in Section 3.24, Spill Risk).

Mine Site

Construction; and Operations and Maintenance

No pre-existing contaminated conditions of environmental concern were identified at the mine site; thus, effects from exposure of existing contaminated soils during construction, operations, or closure are not expected to occur.

Soil quality could be affected by fugitive dust settling on soil, or gaseous mercury emissions that wash out of the atmosphere as wet or dry deposition. Fugitive dust would be generated by processes such as drilling and blasting in the pit, waste rock and ore handling, road traffic, and wind erosion of exposed surfaces such as ore stockpiles and tailings beaches. Fugitive dust generated during mine site construction (pre-production) and operations could potentially result in elevated concentrations of metals in soils surrounding the mine site over time through dust deposition. The dust particulates would reflect the minerals in the source material. Gaseous mercury could be emitted from the mill facility, waste rock, and tailings pond water.

Potential Contaminants in Fugitive Dust

Levels of metals present in baseline soils are listed in Table 3.2-2. As described in Section 3.2.2.1.4, ADEC soil cleanup levels, which are administered through the State's Contaminated Sites Program, are also listed in Table 3.2-2 for comparison purposes to provide a framework for understanding existing conditions. Only arsenic exceeds this level in baseline soils, and is

further evaluated below along with additional constituents predicted to be present in fugitive dust.

Potential fugitive contaminants of concern include mercury from ore processing, as well as other metals present in mine materials that could be potential sources of dust, such as the ore stockpile and tailings solids. Other metals include 10 Hazardous Air Pollutants (HAPs) that have been estimated in various ore and waste rock fugitive dust sources. Table 3.2-12 lists the predicted concentrations of mercury in these sources, as well as additional HAPs metals that are predicted to be present in dust at concentrations exceeding ADEC soil cleanup levels protective of human health. While not currently applicable to the mine site, the ADEC levels were used to identify which metals warrant further analysis of effects on soil quality. Because there are different metals concentrations in different sources, the estimates provided for dust composites are based on a compilation of fugitive dust emissions from various sources, locations, and temporal phases of the mine. Dust combined from all mine sources and phases is predicted to contain 86 percent waste rock and 14 percent ore (Environ 2014a, 2015; Donlin Gold 2015d).

Dust Dispersion in Air

The extent and effects of dust dispersion on air quality surrounding the mine facilities have been analyzed through particulate dispersion modeling conducted by Air Sciences (2014a) using AERMOD and Environ (2015) using CALPUFF. The Air Science results show that air quality compliance for Prevention of Significant Deterioration (PSD) particulate matter (PM) impacts would be met at the closest points of compliance in dominant downwind directions (southeast and northwest), and that PM concentrations would be well below Ambient Air Quality Standards (AAQS) at these locations. Points of compliance for air quality purposes include Calista Corporation and The Kuskokwim Corporation (TKC) property boundaries for which Donlin Gold has surface use agreements, the closest of which are located about 1 mile northwest of the pit, 1 mile south of the TSF, and 1.5 miles east of the WRF. These results are discussed in more detail in relation to air quality impacts in Section 3.8, Air Quality.

Table 3.2-12: Selected Metals Concentrations in Fugitive Dust Sources

Element ¹	Potential Fugitive Dust Sources at Mine Site					Potential Dust Sources along Mine Access Road	ADEC Soil Cleanup Level ⁷ (mg/kg)
	Ore ² (mg/kg)	Tailings ³ (mg/kg)	Waste Rock ² (mg/kg)	Dust Composite ⁴ (mg/kg)	Overburden ⁵ (mg/kg)	Outcrops/Potential Road Base Material ⁶ (mg/kg)	
Antimony	88	120	19	31	-	7.7	41
Arsenic	2,480	910	490	770	134	59	4.5
Mercury (total)	11.7	0.7	8.0	8.6	-	-	30/18

Notes:

1 Only metals exceeding ADEC cleanup levels in baseline or potential dust sources are listed. Values shown are arithmetic means.

2 Data from drill core assay analyses; n = 2,269 to 41,070 (Rieser 2015a).

3 Feasibility Pilot Phase 2 Final Filtrate 2007; n = 1 (SRK 2012b).

4 Estimate for all fugitive dust sources assuming 86 percent waste rock and 14 percent ore (Environ 2014a, 2015; Donlin Gold 2015d).

5 Overburden data from pit area; n = 33 (Fernandez 2014c).

6 Outcrops and rock rubble samples along mine access road, assumed similar to potential borrow pit material to be used as road base; from Fernandez (2014a), n = 2 to 54.

7 18 AAC 75: Method Two, Under 40-inch Zone; direct contact route for antimony and arsenic; direct contact/outdoor inhalation for mercury.

Abbreviations:

- data not available

n number of samples

ADEC = Alaska Department of Environmental Conservation

Shaded cell = Concentrations exceed ADEC soil cleanup levels

Dust Deposition on Soils

The amount of dust that is predicted to be deposited on soils at the mine site and along the mine access road is shown on Figure 3.2-10 and Figure 3.2-11, respectively. These figures provide annual deposition rates in terms of mass per area, as well as the total fraction of dust that is predicted to accumulate in shallow soils at the end of mine life.

For the mine site (Figure 3.2-10), dust deposition was calculated as follows, based on the results of the CALPUFF model used to predict mercury (Hg) deposition:

$$\text{Dust deposition rate (mass/area-time)} = \frac{\text{Hg deposition due to dust (mass/area-time)}}{\text{Hg concentration in dust (mass/mass)}} \quad [\text{Eq. 1}]$$

Because mercury deposition from both fugitive dust and stack sources combined were provided in the Environ (2015) CALPUFF model output (Figure 3.8-5), these values were reduced by the estimated fraction coming from particulates (Hg[p]) in total mercury deposition, in order to derive the value for “Hg deposition due to dust” in Equation 1. Mercury deposition due to fugitive dust alone is estimated to comprise approximately 77 percent of total mercury deposition at the mine site, the rest coming from gaseous mercury forms (Environ 2015). The value for “Hg concentration in dust” used in Equation 1 was the same as that used in the model, or 0.77 ppm overall, based on concentrations of 1.62 ppm in ore and 0.62 ppm in waste rock,

and relative contributions of 14 and 86 percent, respectively (Environ 2014a, 2015, Table 3-7; Donlin Gold 2015d). Tailings were assumed to be composed of waste rock in these estimates.

Estimates of total dust accumulation in soil at the end of mine life, expressed as a mass fraction (Mp) or percent of particulates in soil, are based on the following:

$$M_p = \frac{\text{Dust mass}}{\text{Soil+dust mass}} = \frac{\text{Dust deposition (mass/area-time)} \times \text{area} \times \text{time}}{\text{Soil+dust density (mass/volume)} \times \text{volume}} = \frac{\text{Dust deposition} \times \text{time}}{\text{Soil+dust density} \times \text{depth}} \quad [\text{Eq. 2}]$$

The soil density and depth assumptions used in Equation 2 are the same as those used by ARCADIS (2014) to predict mercury concentrations in soil: a bulk density of 1.5 grams/cubic centimeters (g/cc) was used represent to density of soil and dust combined based on a USGS estimate for silty soils, and a 2 cm (0.8-inch) soil depth was used to capture the maximum effect on near-surface soils. As described by ARCADIS (2014), soils just below this depth and in layers with the highest organic content have been shown to have the greatest potential for metal accumulation. In addition, biotic transfer from dust-affected soils to humans, wildlife, and plants would be most likely to occur at this depth. A value of 35 years was used in Equation 2 to represent the end of mine life and dust-generating activities. This includes 3.5 years for construction, 27.5 years of operations, and 4 years of reclamation activities.

Annual dust deposition rates and the dust fraction in soil at Year 35 are shown on Figure 3.2-10 averaged across several watersheds, which represent USGS Hydrologic Unit Code 12 (HUC12) watersheds used in the Environ (2015) CALPUFF model. Total dust deposition is predicted to be highest in the Eta-Crooked Creek watershed, where shallow soils are predicted to contain about 0.55 percent dust by the end of mine life. While the watershed boundary for this HUC12 watershed extends from the mine site to the Kuskokwim River, the results for the southern portion near Crooked Creek Village are likely to be closer to those of adjacent Village and Bell watersheds and the village itself, which are an order of magnitude less, with predicted levels of dust at 0.05 to 0.06 percent.

The model takes a number of factors into account besides dominant wind direction, such as terrain (ridges), vertical and horizontal dispersion, mixing heights, surface roughness, and vegetation, which could affect the location of dust fallout. While the dominant air transport direction is to the northwest and south-southeast (see Figure 3.8-5 in Section 3.8, Air Quality), the apparent northeast-southwest trend of the deposition map (Figure 3.2-10) is partly an artifact of the model averaging over the large size and trends of the upper Crooked Creek and Donlin Creek HUC 12 watersheds. Most deposition within these two watersheds would be in the portions of the watersheds closer to the mine site. The relatively high deposition value in the upper Crooked Creek watershed reflects the fact that the mine site dust sources would almost entirely be located in that HUC 12 unit. The relatively high value in the Donlin Creek watershed reflects the fact that the pit and WRF would reach or cross the watershed divide with Donlin Creek, and that these two mine components would be the source of about three-quarters of all dust from the mine. In addition, the model conservatively assumes that dust from the pit, which comprises nearly half of fugitive dust emissions, would not be redeposited in the pit (Environ 2015).

Dust deposition for the mine access road (Figure 3.2-11) is further discussed under Transportation Facilities.

Estimated Mercury Concentrations in Soil

Estimated mercury concentrations in soil at the end of mine life were estimated using three different statistical approaches as described below. The objective of this exercise was to determine whether end-of-mine-life concentrations of mercury in soil might represent a concern to human health. Humans or ecological receptors would be exposed to the total concentration of mercury in soil, as represented by the sum of the baseline concentration and the incremental concentration deposited due to mine site activities. In all three methods, soil concentrations at Year 35 were calculated as follows:

$$C_f = M_b C_b + M_p C_p \quad [\text{Eq. 3}]$$

M_b and M_p are the mass fractions of baseline soils and dust, respectively, and C_b and C_p are the mercury concentrations in baseline soil and dust, respectively.

Environ (2015) CALPUFF Model Results

Estimated mercury concentrations in shallow soil at Year 35 are shown on Figure 3.2-12, averaged across the HUC12 watersheds used in the Environ (2015) CALPUFF model. These were calculated based on arithmetic mean concentrations in baseline soils, the geometric mean of mercury in dust, and the same soil density and depth assumptions described above for the mine site (ARCADIS 2014, SRK 2014a, Rieser 2015a). For HUC12 watersheds in the southeastern portion of the study area with no baseline soil data (e.g., Village and Bell watersheds, Figure 3.2-3), samples from adjacent watersheds were used to represent baseline conditions (ARCADIS 2014, Weglinski 2015a).

The results indicate that mercury concentrations could increase over the life of the mine by up to 6 percent in the northern part of Eta-Crooked Creek watershed, and from 0.1 to 1.5 percent in other nearby watersheds (ARCADIS 2014, Environ 2015, SRK 2014a). Grouse Creek watershed exhibits the highest mercury concentration at Year 35 (919 ug/kg) primarily due to higher baseline concentrations.

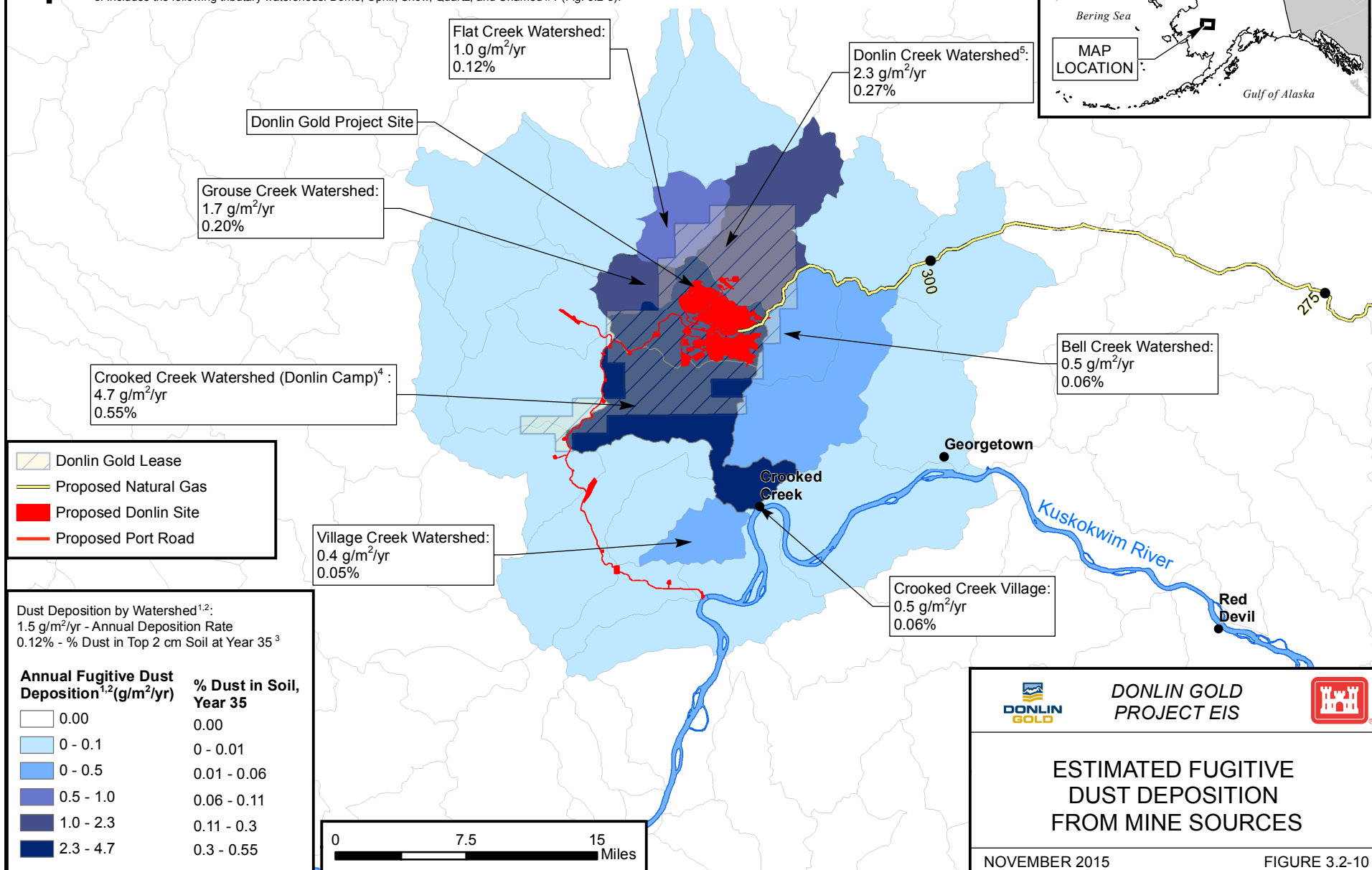
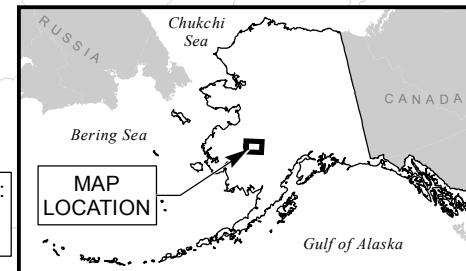
Reasonable Maximum Exposure Concentrations

Mercury concentrations in soil were also estimated using the watershed with the highest fraction of total dust at the end of mine life (0.55 percent, Figure 3.2-10), combined with more conservative statistics for baseline and dust concentrations (95 percent upper confidence limit [95% UCL] for baseline, and arithmetic mean for dust), to explore the upper bounds of potential average exposure concentrations.



Notes:

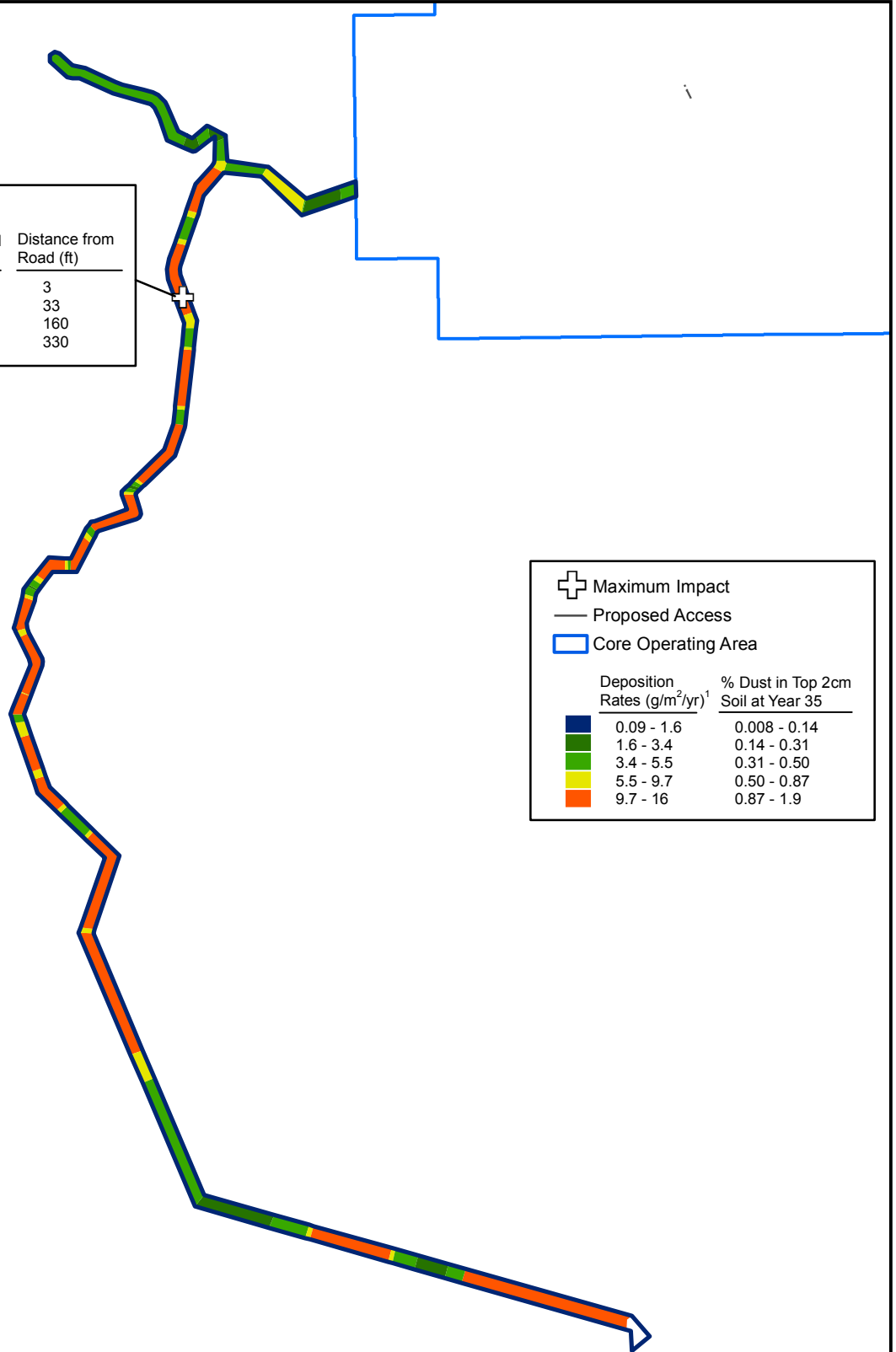
1. Modified from Environ (2015, Fig. 4-4 and Tables 3-7 and 4-4) based on approach and assumptions described in text.
2. Averaged across USGS Hydrologic Unit Code 12 (HUC 12) watersheds.
3. Includes 3.5 years construction, 27.5 years operation, and 4 years closure.
4. Includes the following tributary watersheds: American, Anaconda, Crevice, Eagle, Lewis, Omega, Queen, and Unnamed #1, #2 and SE1 (Fig. 3.2-3).
5. Includes the following tributary watersheds: Dome, Ophir, Snow, Quartz, and Unamed #1 (Fig. 3.2-3).





Location of Maximum Impact:

Dust Deposition Rate (g/m ² /yr) ¹	% Dust in Soil Year 35	Distance from Road (ft)
16	1.9	3
10	1.2	33
1.6	0.19	160
0.8	0.09	330



- ⊕ Maximum Impact
- Proposed Access
- Core Operating Area

Deposition Rates (g/m ² /yr) ¹	% Dust in Top 2cm Soil at Year 35
0.09 - 1.6	0.008 - 0.14
1.6 - 3.4	0.14 - 0.31
3.4 - 5.5	0.31 - 0.50
5.5 - 9.7	0.50 - 0.87
9.7 - 16	0.87 - 1.9

Source: Air Sciences (2015, Fig. 5)

Notes:

1. Annualized based on 110 days/year seasonal use (Donlin Gold 2015e).

0 2.5 5 Miles



**DONLIN GOLD
PROJECT EIS**



**ESTIMATED FUGITIVE DUST
DEPOSITION ALONG MINE
ACCESS ROAD**

NOVEMBER 2015

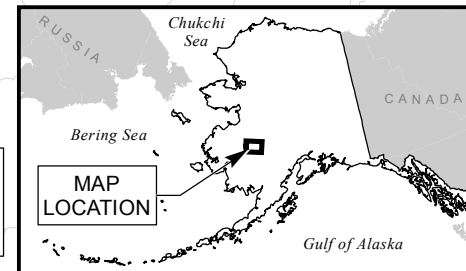
FIGURE 3.2-11



Sources: Arcadis (2014), Environ (2015), and SRK (2014a), extrapolated to year 35.

Notes:

1. Includes approximately 77% contribution from fugitive dust and 23% from stack sources, averaged across USGS HUC 12 watersheds (Environ 2015).
2. Includes 3.5 years construction, 27.5 years operations, and 4 years reclamation.



Flat Creek Watershed:
Baseline Hg - 192 µg/kg
Year 35 - 193 µg/kg
% Increase - 0.5%

Donlin Creek Watershed:
Baseline Hg - 192 µg/kg
Year 35 - 195 µg/kg
% Increase - 1.5%

Grouse Creek Watershed:
Baseline Hg - 917 µg/kg
Year 35 - 919 µg/kg
% Increase - 0.2%

Crooked Creek Watershed (Donlin Camp):
Baseline Hg - 93.9 µg/kg
Year 35 - 99.5 µg/kg
% Increase - 6.0%

Bell Creek Watershed:
Baseline Hg - 917 µg/kg
Year 35 - 918 µg/kg
% Increase - 0.1%

Village Creek Watershed:
Baseline Hg - 71.2 µg/kg
Year 35 - 71.6 µg/kg
% Increase - 0.5%

**Mean Concentration of Total Mercury
in Soil (µg/kg) by Watershed ¹:**
Baseline - 192
Year 35² - 193
% Increase - 0.5%

**Annual Deposition of Total
Mercury (µg/m²/yr)¹**

- 0.00
- 0.06
- 0.30
- 0.55
- 0.99
- 2.3 - 4.83

Donlin Gold Lease

Proposed Natural Gas Pipeline

Proposed Donlin Site Layout

Proposed Port Road

0 7.5 15 Miles



DONLIN GOLD
PROJECT EIS



**ESTIMATED CONCENTRATIONS
OF MERCURY IN SOIL FROM
DUST AND STACK SOURCES**

NOVEMBER 2015

FIGURE 3.2-12

In the evaluation of contaminated sites, a long-established and commonly used statistic to represent exposure concentrations in soil is the 95% UCL on the mean (EPA 1989, 1992, 2002c). This value represents an upper bound estimate of the mean and the level of confidence in it (i.e., 95 percent of the time, the true mean would fall below the 95% UCL). It is considered a conservative “reasonable maximum exposure” concentration for human health risk assessment by the EPA (1989, 2013a), who analyzed different distributions and skewed data sets in order to provide an appropriate mean to be used for this purpose. The rationale for using the 95% UCL of the mean as an exposure concentration is that a human or ecological receptor would not be expected to spend long durations exposed only to the maximum values in an area. Rather, because of the heterogeneous nature of chemical distributions in soil and the mobility of most receptors, the average is considered to better represent potential exposures, and the use of maximum values or similar upper range values, such as upper prediction limits (UPLs) or 95th percentiles of the actual distribution, would be inappropriate.

Because sampling for future concentrations in soil is not possible, a modified approach to predicting upper-bound estimates of future mean concentrations was adopted. The 95% UCL of current baseline concentrations was estimated based on field sampling, and an incremental mercury addition based on the arithmetic mean of predicted dust deposition rates in the watershed with the highest level of dust (Crooked Creek watershed) was estimated separately. For dust estimates, the arithmetic mean is notably higher than the geometric mean used in the Environ (2015) model. This is because the dust data, which are derived from the pit resource block model dataset, are positively skewed and influenced by high-value outliers (Rieser 2015a). Thus, use of the arithmetic mean for dust, when added to either the 95% UCL or arithmetic mean for baseline, is considered more conservative than that of the Environ (2015) model. Thus, the total predicted concentration was estimated by addition of the arithmetic mean incremental concentration to the baseline 95% UCL (i.e., final concentration = 95% UCL of baseline + arithmetic mean of increment). This final value was compared to health-protective values for mercury in soil.

The purpose of this exercise was not to “dilute” out the incremental concentrations or to make the increment appear to be proportionately small in comparison to baseline. Rather, the goal was to develop a final total concentration that may be used as a conservative reasonable maximum exposure concentration for risk-based comparisons. By using the 95% UCL of the baseline and the mean increment from the likely most impacted watershed, a conservative exposure concentration was developed that is consistent with EPA risk assessment methodology. Other possible variations of this approach would be expected to yield similar conclusions.

Comparable Arithmetic Means

An estimate of mercury in soil at the end of mine life was also calculated using arithmetic means for both baseline and dust, in order to identify the incremental contribution from the mine using comparable statistics. The site-wide population of baseline data was used for these calculations. As shown in Table 3.2-2 and Table 3.2-13, arithmetic mean baseline concentrations are notably lower than the 95% UCLs. This approach provides a more conservative estimate of the mine contribution than the other two methods, but results in a lower end concentration.

As shown in Table 3.2-13, the use of the 95% UCL and mean baseline data, combined with the highest predicted dust fraction in soil (0.55 percent) and mean dust data, result in estimated increases in mercury concentrations in soil in the range of 11 to 22 percent. However, given the

low level of mercury in baseline samples and dust compared to ADEC soil standards, these predicted increases would raise total mercury in soils to concentrations that are still one to two orders of magnitude below soil cleanup levels, indicating a low intensity of effects on human health as intended by the ADEC standards. The potential effects of increased mercury that could be methylated in wetlands and bioaccumulate in biota are described in Section 3.7, Water Quality, and Section 3.12, Wildlife.

Table 3.2-13: Estimated Metals Concentrations in Mine Site Soil due to Fugitive Dust

Element ¹	Current Soil Concentration ² (mg/kg)	Dust Composite ³ (mg/kg)	% Dust in Soil, Year 35 ⁴	Soil, Year 35		ADEC Soil Cleanup Level ⁵ (mg/kg)
				Concentration (mg/kg)	% Increase above Baseline	
Antimony						
mean	5.35	31	0.55	5.48	2.4	41
95% UCL	11.1	-		11.2	0.9	
Arsenic						
mean	78.8	770	0.55	82.6	4.8	4.5
95% UCL	169	-		172	1.9	
Mercury (total)						
mean	0.212	8.6	0.55	0.258	22	30/18
95% UCL	0.415	-		0.460	11	

Notes:

- 1 Only metals exceeding ADEC cleanup levels in baseline or potential dust sources are listed.
- 2 Site-wide baseline values from Table 3.2-2 (Fernandez 2014a; ARCADIS 2007c, 2014).
- 3 Arithmetic mean of all fugitive dust sources at the mine assuming 86 percent waste rock and 14 percent ore (Environ 2014a, 2015; Donlin Gold 2015d).
- 4 Highest watershed-based value in Figure 3.2-10, based on CALPUFF model results in Environ (2014a) extrapolated to total dust deposition (see Equations 1 and 2 in text).
- 5 18 AAC 75: Method Two, Under 40-inch Zone; direct contact route for antimony and arsenic; direct contact/outdoor inhalation for mercury.

Abbreviations:

- data not available

n number of samples

95% UCL 95 percent upper confidence limit on the mean

ADEC = Alaska Department of Environmental Conservation

Shaded cell = Concentrations exceed ADEC levels.

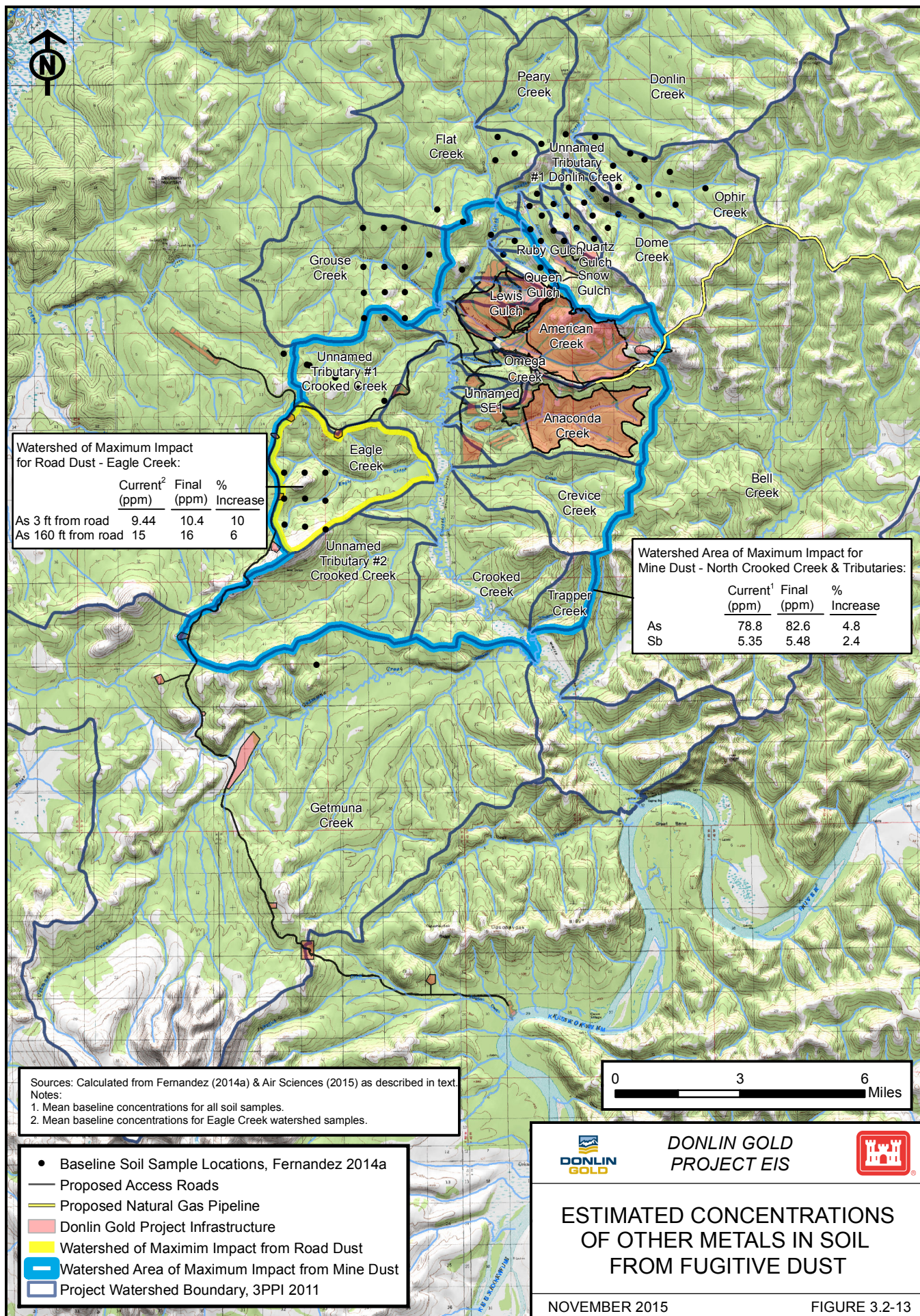
Estimated Concentrations of Other Metals in Soil

The geochemistry of baseline soils and potential dust sources, combined with comparisons to ADEC levels, suggest that other metals of potential concern for soil quality include antimony and arsenic. The effects of these constituents on soils from fugitive dust deposition have not been specifically modeled, as mercury has. Instead, their concentrations in soil at the end of mine life were estimated based on the HUC12 watershed with the highest fraction of dust extrapolated from the Environ (2015) CALPUFF model (Figure 3.2-10, and Equations 1 and 2). The boundaries of this watershed, the northern portion of Eta-Crooked Creek, are shown on Figure 3.2-13 compared to the distribution of baseline soils samples. Because the watershed is not well represented by the distribution of existing sample locations, the site-wide population of baseline data was used for the arsenic and antimony estimates.

Year 35 soil concentrations were estimated using two of the methods described above for mercury: 1) using the 95% UCL concentrations for baseline soils plus arithmetic mean for dust to identify reasonable maximum average exposure concentrations for the final soil concentration; and 2) using the arithmetic mean for both baseline and dust to identify a more representative and conservative value for the incremental percent increase caused by the mine.

Dust composite concentrations for antimony and arsenic are based on numerous samples in the resource block model database (Rieser 2015a). The average concentration of each from this database was used to estimate the dust composite using the same relative contributions from ore and waste rock that were used for mercury (14 and 86 percent, respectively) (Environ 2014a, 2015). Because the dust composite ratio for mercury was derived from sources that apply to waste rock and ore as a whole, and do not include mercury-specific stack emissions, the same relative contributions were used for other metals in the soil analysis.

Based on the above approach, the concentration of antimony and arsenic in soil were estimated to increase by about 1 to 5 percent by the end of mine life (Table 3.2-13). The lower percent increases are associated with higher baseline and final concentrations (using 95% UCL for baseline), and provide a reasonably conservative estimate of final soil concentrations. The higher percent increases are associated with lower baseline and final concentrations (using means for baseline), and provide a reasonably conservative estimate of contribution from the mine. While concentrations of arsenic in soils outside of the footprint of the mine are likely to exceed baseline and ADEC levels over the mine life due to the relatively high concentrations in both baseline soils and dust, the percent increases are relatively minor. As described in Section 3.22 (Human Health), the human health risk associated with the incremental amount of project-related arsenic in soils does not exceed ADEC acceptable risk levels for contaminated sites, is considered insignificant compared to baseline, and of low intensity. ADEC cleanup levels can be modified for elevated background conditions, as is often the case for arsenic which is naturally elevated throughout western Alaska. The lateral extent of dust deposition (Figure 3.2-10) suggests that arsenic contributions from mine dust are likely to reach negligible levels within 5 to 10 miles of the mine footprint. Potential impacts to ecological and human receptors are further analyzed in Sections 3.10, Vegetation; 3.12, Wildlife; and 3.22, Human Health.



Dust Deposition Effect on Soil Acidity

It is possible that fugitive dust deposition could cause minor changes in soil acidity from sulfide minerals in dust emitted from ore sources. About 3.5 percent of estimated fugitive dust is anticipated to be from ore sources and the remainder from waste rock sources (Air Sciences 2014a). Existing baseline soil conditions are slightly acidic, with pH averaging about 4.5 to 4.7 for wetlands and uplands soils, respectively (ARCADIS 2014), indicating little to no buffering capacity. Assuming that the sulfide content of the ore component of the dust is 1.5 percent (SRK 2011; SRK 2013b), the acid generating potential (AP) of the ore dust would be equivalent to 46.9 tonnes CaCO_3 /kilotonne (t CaCO_3 /kt). The carbonate neutralization potential (NP) of the ore is assumed to be similar to that of PAG7 waste rock or 4.6 t CaCO_3 /kt (Enos 2013c). In contrast, the tonnage-weighted average of all waste rock types would have an AP of 11.0 t CaCO_3 /kt and an NP of 60.5 t CaCO_3 /kt (Enos 2013c). Applying the percentage of ore in the dust to these values, the overall net NP of the dust would be 46 t CaCO_3 /kt, and the overall NP to AP ratio of the dust would be 4.7, meaning that the dust has the capacity to neutralize 4.7 times more acid than it can generate. In other words, the large excess of NP in the waste rock, which would comprise the majority (96.5 percent) of the dust, would be more than sufficient to counteract the AP of the ore component, and the net effect of dust deposition would be a minor increase in both the buffering capacity and the alkalinity of soils in the vicinity of the mine site.

Cyanide emitted from the process plant is anticipated to be primarily an air quality impact (see Section 3.8, Air Quality) and is expected to have little effect on soil quality. The atmosphere is considered the ultimate sink for almost all cyanide. Although small amounts may be present in PM, cyanide is not expected to persist in soil due to volatilization and biodegradation (ATSDR 2006).

Dust Control at Mine Site

The fugitive dust estimates described in the above analyses by Air Sciences (2014a) and Environ (2015) assume that dust suppression for emission reduction would not occur, except in the case of unpaved roads. For example, no dust suppression is assumed for the WRF, tailings beach, or pit. Unpaved roads are assumed to be controlled at 90 percent, primarily with periodic chemical application and watering (Rieser 2015b). In addition, the mercury model (Environ 2015) conservatively assumes that none of the dust from the pit, which comprises nearly half of fugitive dust mercury emissions from the mine site, would be redeposited in the pit.

The project design includes a number of best practical measures (BPMs) that would minimize wind erosion and fugitive dust, and limit traffic and soil disturbance during construction and operations. These include plant baghouses; an enclosed structure for coarse ore; stabilization of disturbed soil by truck watering, spreading snow, or applying other approved dust suppressants; allowing natural conditions (e.g., rain and snow) to maintain dust control until use of conventional methods is necessary; the use of evaporative sprayers at the TSF (to minimize stored water volume) that could also be directed for tailings beach dust control; and the use of a phased approach for soil disturbance and reclamation, and dozers for soil compaction, at the WRF and other reclaimed areas. These measures would be detailed in a Fugitive Dust Control Plan (FDCP) prior to construction (Rieser 2015b, BGC 2015f).

Closure, Reclamation, and Monitoring

Dust is expected to be generated during reclamation activities. Four years of the closure period were included in the dust estimates described above (under Construction, and Operations and

Maintenance) to provide reasonable maximum exposure concentrations at the end of mine life that include earth-moving activities in early closure. The concentrations of metals in the dust during reclamation, however, would be lower than those from mine operations, as the source of the dust would be mostly from overburden and growth media with concentrations closer to baseline values. Thus, the impacts of dust on soil quality during reclamation are expected to be of low intensity.

Summary of Mine Site Impacts

The effects of dust deposition on soil quality during construction, operation, and closure of Alternative 2 would be of low intensity, in that increases for mercury and antimony would not reach levels of concern, and arsenic is expected to exhibit a small increase (up to 5 percent) above naturally high baseline concentrations. While baseline concentrations of arsenic are more than an order of magnitude higher than ADEC levels, the additional sources of arsenic mobilized by the mine would contribute a relatively small increase in soil concentrations over the life of the mine. Planned mitigation measures for dust control are expected to minimize the levels of these effects. Effects are expected to be range from local to regional, mostly affecting nearby watersheds within Project Area boundaries, but could be measurable as far as 10 miles from the mine. Effects would be permanent, potentially accumulating and persisting over the life of the mine and remaining at similar levels following mine closure. Soil quality effects are considered common in context, in that the soils affected are regionally extensive, and it is unknown whether they would be subject to future ADEC oversight due to potential dust impacts.

Transportation Facilities

Construction

Mine Access Road: No pre-existing contaminated sites were identified along the mine access road corridor.

Dust generated during road construction and from road use during mine construction could potentially result in elevated concentrations of certain metals in soils near the road over time through dust deposition. Similar to the discussion above under Mine Site, potential contaminants of concern could include metals if present at elevated concentrations in source material (rock or overburden from material sites) used as slope fill or road base. While the concentrations of metals at specific road material sites are unknown, samples of various outcrops and rock rubble along the road corridor that may be representative of potential bedrock borrow material exhibit arsenic levels that are roughly similar to those of site-wide baseline soils (Table 3.2-16).

Dust deposition rates and dust fractions in soil are shown on Figure 3.2-11 for the mine access road based on a model completed by Air Sciences (2015a) using AERMOD. Daily dust deposition rates provided in the Air Sciences (2015a) report were annualized on this figure based on 110 days/year seasonal use (Donlin Gold 2015e). The fraction of dust that accumulates in shallow soils by the end of mine life were calculated using Equation 2 (described above under Mine Site, Dust Deposition on Soils) and the same soil density, depth, and time assumptions used for the mine site.

The location of maximum dust deposition along the road is in Eagle Creek watershed about 2 miles south of the airstrip spur road (Figure 3.2-11 and Figure 3.2-13). The fraction of dust that is expected to accumulate in soil at this location by the end of mine life is about 1.9 percent immediately adjacent to the road. This amount drops off by an order of magnitude (to 0.19 percent) about 160 feet from the road.

Concentrations of arsenic in soil at the end of mine life due to road dust were estimated based on baseline soil data from the Eagle Creek watershed (Figure 3.2-3 and Figure 3.2-13). Antimony is not elevated with respect to ADEC levels for potential road dust sources (Table 3.2-12); thus, it was not included in this analysis. No baseline soil mercury data are available specifically for the Eagle Creek watershed or for outcrop/rubble samples. Because this watershed is located within the boundaries of the larger HUC12 watershed with highest predicted mine dust impacts (Figure 3.2-13), the mercury results for the road location are estimated to be the same as those described above under Mine Site.

Year 35 soil concentrations for arsenic were estimated in Table 3.2-16 using Equation 3 and both the arithmetic mean and 95 percent UCL concentrations for baseline soils to identify reasonable upper bound estimates associated with the incremental increase caused by road dust and final soil concentrations. The results indicate that arsenic concentrations could increase by about 8 to 10 percent in soils immediately adjacent to the road, and drop to a 1 percent increase 160 feet from the road. Estimated final soil concentrations are less than those predicted for the mine site (Table 3.2-15), because arsenic concentrations at borrow sites are expected to be substantially less than those of waste rock and ore that comprise dust sources at the mine site. Effects would be mostly of low intensity, in that over time concentrations are not expected to substantially exceed baseline levels and would be within the range of natural variation in the site vicinity, although concentrations would slightly exceed ADEC levels protective of human health, as they are already elevated in baseline soils. Concentrations could increase towards the north end of the road where dust may be more representative of waste rock and ore data than outcrop data (Table 3.2-12). Additional evaluation of metals leaching at material sites prior to construction and planned mitigation measures for dust control (e.g., water trucks) (Chapter 5, Impact Avoidance, Minimization, and Mitigation), would minimize the level and extent of effects.

Kuskokwim River Corridor: Multiple existing contaminated sites are present within ¼ mile of the Kuskokwim River, downstream from the Angyaruaq (Jungjuk) Port, most of which coincide with established river communities (Table 3.2-5 and Figure 3.2-4). Petroleum hydrocarbons are the most prevalent contaminant amongst sites identified. More than half of the sites are designated as “open” by ADEC, indicating that contamination persists at concentrations above established cleanup levels, or insufficient information is available to make a determination. Established institutional controls exist for one site, which are limited to groundwater usage restrictions.

Table 3.2-14: Estimated Arsenic Concentrations in Soil along Mine Access Road due to Fugitive Dust

Element ¹	Current Soil Concentration ² (mg/kg)	Outcrop/ Rock Rubble ³ (mg/kg)	% Dust in Soil, Year 35 ⁴	Soil, Year 35		ADEC Soil Cleanup Level ⁵ (mg/kg)
				Concentration (mg/kg)	% Increase above Baseline	
Arsenic – 3 feet from road						
mean	9.44	59	1.9	10.4	10	4.5
95% UCL	11.8	-		12.7	7.6	
Arsenic – 160 feet from road						
mean	9.44	59	0.19	9.5	1.0	4.5
95% UCL	11.8	-		11.9	0.8	

Notes:

- 1 Only metals exceeding ADEC cleanup levels in baseline or potential road dust sources are listed.
- 2 Baseline samples from watershed with maximum dust deposition - Eagle Creek (Air Sciences 2015a, Fernandez 2014a). based on 95% Student's-t UCL
- 3 Outcrops and rock rubble samples along mine access road, assumed similar to potential borrow pit material to be used as road base; from Fernandez (2014a).
- 4 Maximum impact value on Figure 3.2-11, based on AERMOD results in Air Sciences (2015a) extrapolated to soil fraction at Year 35 (see Equation 2 in text).
- 5 18 AAC 75: Method Two, Under 40-inch Zone; direct contact route.

Abbreviations:

- data not available

n number of samples

95% UCL = 95 percent upper confidence limit on the mean

ADEC = Alaska Department of Environmental Conservation

Shaded cell = Concentrations exceed ADEC levels.

Based on the proximity of multiple open contaminated sites along the river corridor, residual soil contamination could be a source of off-site contaminant migration to adjacent surface waters via erosion from intrusive construction activities; however, since no proposed project infrastructure coincides with any of the contaminated sites, there would be no impacts to soil quality. The potential for effects from wake-induced shoreline erosion from barge traffic would require the following conditions be met:

- Soil contamination has sufficiently migrated through soils from inland sources to the Kuskokwim River shoreline;
- Contamination is present in vadose soils (above water table) that could potentially slough into the Kuskokwim River from wave-induced barge traffic. However, in most circumstances associated with shoreline discharge scenarios, contaminant migration to surface water bodies from inland sources is generally via groundwater seeps, or baseflow intrusion;
- Contaminant type (source) and concentrations are sufficient to have a detectable and quantifiable impact at the point of discharge (bank sloughing); and
- Wake-induced erosion can be differentiated from other on-going natural shoreline processes. As noted in Section 3.2.3.2.2 and Section 3.5, Surface Water Hydrology, natural erosion effects from ice breakup and flooding along the Kuskokwim River are likely to be substantially greater than barge wake-induced erosion.

While readily available ADEC information is insufficient to evaluate effects on an individual site basis, due to the combination of conditions that would have to be satisfied to have an appreciable impact, the likelihood and intensity of potential effects is considered low. The duration of effects (if any) would be long-term since barge traffic would occur over the life span of the project. The geographic extent would be limited to point sources where the required conditions exist, and are therefore considered local. The context is considered common to important, based on a combination of widespread soil types, ongoing shoreline erosion processes present along the river, and contaminated sites that are governed by regulation.

Bethel Cargo and Fuel Terminals and Tank Farm: Although several contaminated sites exist in the vicinity of the terminals and tank farm in Bethel, only one lies within the proposed boundary of potential port construction (Figure 3.2-4 and Table 3.2-5). As described in Section 3.2.2.2.4, other contaminated sites in the vicinity were considered unlikely to impair soil conditions within the project boundaries due to sufficient distance, hydraulic gradients, and/or presence of permafrost. The contaminated site within the project boundary is associated with a petroleum release at the Bethel Fuel Sales facility, which ADEC gives a “cleanup complete” status. Furthermore, the site is already developed and is equipped with pads, liners, and containment to accommodate 3 additional tanks, indicating that intrusive construction work would be limited during tank farm expansion and discovery of additional undocumented contaminated soils unlikely. Thus, little to no impacts is expected from disturbance of contaminated soils at this site.

Dutch Harbor Port: Fuel capacity expansion at the Dutch Harbor Port by a third party could potentially involve disturbance of areas impacted with contaminated soil or other media. A total of 17 contaminated sites are located within approximately ¼-mile of existing tank farms and docks (Figure 3.2-5 and Table 3.2-6). Three of the sites are closed and 14 are open contaminated sites. Four of the open sites coincide with existing tank farm and dock locations, including the Delta Western bulk plant and dock pipelines, and the Rocky Point tank hill and lower tank. The nature of contamination at each of these sites is petroleum hydrocarbons derived from storage tank releases, pipeline releases, fuel handling practices, subsurface utility infrastructure, and comingling hydrocarbon contamination from WWII era operations or other historic land uses. Impacted media includes soil and groundwater. Non-aqueous petroleum product is also present in some circumstances. Groundwater is often shallow (less than 10 feet), in addition to a shallow bedrock interface. ADEC interaction with site owners/representatives is on-going (ADEC 2013a).

Due to the present and historical complexity of environmental concerns at these sites, the effects on soil quality from construction activities largely depends on the location of the fuel expansion area, and the site-specific presence of pre-existing conditions of concern. Anticipated construction and/or fuel service provider responsibilities would likely require preparation and execution of any necessary permits or regulatory required processes, including SWPPP preparation, contaminated media investigation planning and approval by the ADEC's Contaminated Sites Program, and remediation as appropriate. The anticipated intensity of effects from construction could range from low to medium, depending on the presence and extent of existing soil contamination, remediation practices, and site controls employed during cleanup. The duration of pre-existing soil contamination (if any) could range from temporary (if concurrent soil remediation is practicable and performed during construction) to long-term, depending on the severity of contamination and ADEC-approved remediation approach. Regardless, the duration of effects would be an ongoing responsibility of the third-party

landowner, or responsible party. Resulting effects would be beneficial if required remediation results in reduced soil/water quality impairment. Due to the estimated small size of the expanded tank farm area required, the extent of effects would be local, i.e., within the immediate vicinity of the tank farm expansion footprint. Since similar surface and subsurface soil conditions (soil types and/or presence of impacted soil media) exist throughout the Dutch Harbor area, and contaminated sites are governed by regulation, the context is considered common to important.

Operations and Maintenance; and Closure, Reclamation, and Monitoring

Little to no incremental effects from contaminated sites are expected during operations and closure at the transportation facilities beyond those described above. It is possible that if remediation is required at the Dutch Harbor Port, the duration of cleanup could extend into the operations period or beyond. The level of effects though would be the same as described above.

Effects from dust generated along the mine access road during operations and closure would be the same as described above under Construction.

Summary of Transportation Facilities Impacts

Impacts to soil quality for dust along the mine access road, and from contaminated sites at the various transportation infrastructure facilities during construction, operation, and closure of Alternative 2, would range from low intensity (e.g., small increase in arsenic immediately adjacent to road above slightly elevated baseline soil concentrations, with final concentrations within the range of natural variation) to medium intensity (e.g., contaminated sites at Dutch Harbor, depending on site-specific presence/extent of existing soil contamination). However, additional evaluation of metals leaching at borrow sites, dust control along the road, SWPPP compliance, and remediation (Chapter 5, Impact Avoidance, Minimization, and Mitigation) are expected to be effective in controlling effects on the project, and in controlling potential third-party construction activities from spreading any pre-existing contamination. Effects are expected to be localized within the immediate vicinity of individual facilities, and in the case of road dust, would drop to negligible levels within a few hundred feet from the mine access road. Effects from contaminated sites would be temporary to long-term in duration, depending on the nature of required remediation (if any). Dust effects along the road would be permanent, potentially accumulating over the mine life and persisting into post-closure. Effects are considered common to important in context, in that the soils affected are regionally extensive and contaminated sites are governed by regulation.

Natural Gas Pipeline

Construction

Potential effects from contaminated sites are not applicable to pipeline trenching or ROW preparation since no pre-existing contaminated conditions of environmental concern have been identified along the pipeline ROW (Table 3.2-10 and Figure 3.2-9). Several “open” contaminated sites were identified in the vicinity of the proposed Beluga camp and storage yard. These are unlikely to have an effect on project activities, however, because they are associated with specific Beluga Power Plant and Beluga Gas Field infrastructure that would not be disturbed by

pipeline construction activities, and because construction of the camp and storage yard would not involve any cuts or subsurface excavations.

Open sites identified at one of the existing airstrips proposed for use during pipeline construction (Farewell) could have an effect on the project if airstrip grading requirements disturb existing petroleum-contaminated soils originating from heating oil tanks and pipelines near Federal Aviation Administration (FAA) structures at the site. In this event, the type and level of effects would be similar to those described above for Dutch Harbor, with responsibility for remediation residing with FAA. Mitigation recommendations are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation, for additional investigation prior to pipeline construction to map the specific location of potential contaminated soils compared to final grading plans, so that disturbance of these soils can be avoided if possible, and the level of effects reduced to low likelihood and intensity.

Operations and Maintenance; and Closure, Reclamation, and Monitoring

Little to no incremental effects from contaminated sites are expected during operations and closure at the pipeline beyond those described above, as the off-ROW sites located near pre-existing open contaminated sites would not be utilized after construction. Post-construction reclamation at the Beluga camp and storage yard would not involve any intrusive actions (excavations), and the Farewell airstrip would not be reclaimed after construction.

Summary of Natural Gas Pipeline Impacts

Impacts from contaminated sites along the pipeline during construction, operation, and closure of Alternative 2 could range from low to medium intensity (e.g., grading of pre-existing contaminated soils at the Farewell airstrip), depending on the site-specific presence and extent of existing soil contamination; however, additional investigation during final design would likely allow disturbances of these soils to be avoided and reduce potential effects to low intensity. Effects on the project are expected to be localized within airstrip boundaries, and would be temporary, lasting through construction only. Effects are considered common to important in context, in that the soils affected are regionally extensive, but are governed by regulation.

3.2.3.2.5 CLIMATE CHANGE

Predicted overall increases in temperatures and precipitation and changes in the patterns of their distribution have the potential to influence the projected effects of the Donlin Gold Project on soils. These effects are particularly tied to changes in permafrost and increased risk of erosion as discussed in Sections 3.26.4.2.3 and 3.26.4.2.2.

3.2.3.2.6 SUMMARY OF ALTERNATIVE 2 IMPACTS

Table 3.2-15 presents the impact levels of Alternative 2 by project component and impact type, with examples provided for various impact criteria in parentheses. A descriptive summary for each component follows.

Table 3.2-15: Summary of Impacts to Soils for Alternative 2

Project Component	Impact Type/ Phase or Location	Magnitude or Intensity	Duration	Extent	Context	Summary Impact Rating ²
Mine	Soil Disturbance					Minor to Moderate, with low probability of specific major permafrost impacts
	Construction and Operations	Medium (compaction) to High (complete removal).	Permanent (alteration of surface soils).	Local (within footprint of mine site).	Common (based on regional distribution).	
	Closure	Medium (intensity reduced through reclamation).				
	Permafrost					
	TSF, Water Dams, Stockpiles, Plants	Low (minor ground settlement) to Medium (design adequate for conditions).	Long-Term (thaw equilibrium reached over mine life) to Permanent (permafrost recovery not expected).	Local (within footprint of mine site).	Common (based on regional distribution).	
	WRF	Low probability ¹ of Medium to High intensity effects (toe instability if deep ice-rich soils present).				
	Erosion					
	Construction, Operations, Closure	Low to Medium (with BMPs and ESCs measures in design).	Temporary (lasting months) to Long-term (revegetation criteria met in Closure).	Local, within footprint of mine site.	Common to Important (erosion control governed by regulation).	
	Post-Closure	Low (after stabilization achieved).				
	Soil Quality					
	Fugitive Dust Deposition	Low (1 to 5% arsenic increase above naturally high baseline, averaged across large watershed).	Permanent (persisting in soils after Closure).	Local (mostly within property boundaries) to Regional (10 miles away).	Common (based on regional distribution).	

Table 3.2-15: Summary of Impacts to Soils for Alternative 2

Project Component	Impact Type/ Phase or Location	Magnitude or Intensity	Duration	Extent	Context	Summary Impact Rating ²
Transportation Facilities	Soil Disturbance					Minor to Moderate
	Construction and Operations	Low (minor compaction) to High (complete removal at certain facilities).	Permanent (alteration of surface soils).	Local (within footprints of individual facilities).	Common (based on regional distribution).	
	Closure	Low to Medium (intensity reduced through reclamation).				
	Permafrost					
	All Facilities (where permafrost present)	Low (minor ground settlement) to Medium (thermal erosion at port stockpile, or settlement along short road segments and ports, where design adequate for conditions).	Long-Term (thaw equilibrium reached) to Permanent (permafrost recovery not expected).	Local, within immediate vicinity of facility footprints.	Common (based on regional distribution).	
	Erosion					
	Project Facilities: Construction, Operations, Closure	Low to Medium (assuming BMPs and ESCs measures in place and effective).	Temporary (lasting months) to Long-term (revegetation criteria met in closure).	Local, within immediate vicinity of facility footprints.	Common to Important (erosion control governed by regulation).	
	Project Facilities: Post-Closure	Low (after stabilization achieved).				
	ORV Access (Indirect Effects)	Medium (measurable compaction) with intermittent High (organic, ice-rich soils).	Long-term (years) to Permanent	Local to Regional (within several miles of road).		
	Soil Quality					
	Contaminated Sites	Low (co-location with contaminated sites unlikely) to Medium (at Dutch Harbor, depending on site conditions).	Temporary to Long-term (depending on required remediation).	Local, within immediate vicinity of facility footprints.	Common (governed by regulation).	

Table 3.2-15: Summary of Impacts to Soils for Alternative 2

Project Component	Impact Type/ Phase or Location	Magnitude or Intensity	Duration	Extent	Context	Summary Impact Rating ²
Transportation Facilities (continued)	Fugitive Dust Deposition (mine Access Road)	Low (8 to 10% increase in arsenic above slightly elevated baseline immediately adjacent to road).	Permanent (persisting in soils after closure).	Local (effects drops to negligible within 160 ft of the road).		Minor to Moderate
Pipeline	Soil Disturbance					Minor to Moderate
	Construction	Low (minor compaction) to High (complete removal at cuts and certain facilities).	Permanent (alteration of surface soils).	Local (within footprints of ROW and individual facilities).	Common (based on regional distribution).	
	Post-Construction Reclamation, Operations, and Closure	Low to Medium (intensity reduced through reclamation).				
	Permafrost					
	Construction, Operations, Closure	Low (minor ground settlement) to Medium (BMPs effective for addressing measurable settlement).	Long-Term (thaw equilibrium reached) to Permanent (permafrost recovery not expected).	Local, within immediate vicinity of facility footprints.	Common (based on regional distribution).	
	Post-Closure	Low (minor ground settlement) to High (site-specific settlement post-SRR plan).				
	Erosion					
	Project Facilities: Construction and Post-Construction Reclamation	Low to Medium (managed effectively though BMPs), with isolated incidences of High intensity.	Temporary (lasting months) to Long-term (revegetation criteria met in operations).	Local, within immediate vicinity of facility footprints.	Common to Important (erosion control governed by regulation).	
	Project Facilities: Operations and Closure	Low (after stabilization achieved).				

Table 3.2-15: Summary of Impacts to Soils for Alternative 2

Project Component	Impact Type/ Phase or Location	Magnitude or Intensity	Duration	Extent	Context	Summary Impact Rating ²
Pipeline (continued)	ORV Access (Indirect Effects)	Mostly Medium with discrete areas of High (potential heavy seasonal use near Farewell).	Long-term (years) to Permanent.	Local to Regional (miles beyond ROW if used to access new areas).		Minor to Moderate
	Soil Quality					
	Contaminated Sites	Low to Medium (Farewell airstrip).	Temporary (construction phase).	Local, within immediate vicinity of facility footprint.	Common to Important (governed by regulation).	

Notes:

- 1 Low probability considered unlikely but plausible over project life, not a worst-case scenario.
2. The summary impact rating accounts for impact reducing design features proposed by Donlin Gold and Standard Permit Conditions and BMPs that would be required. It does not account for additional mitigation measures the Corps is considering.

ESC = Erosion and Sedimentation Control

BMP = Best management practice

TSF = Tailings Storage Facility

WRF = Waste Rock Facility

SRR = Stabilization, Rehabilitation and Reclamation

ORV = off-road vehicle

Direct impacts to soils from ground disturbances, permafrost degradation, erosion, and fugitive dust at the mine site under Alternative 2, as well as impacts from permafrost hazards on man-made structures, would range from low to high intensity, although the intensity for most effects would be reduced to medium through reclamation or additional mitigation. Soil removal would result in the permanent alteration of a total of roughly 9,000 acres of soil and discontinuous permafrost. Likewise, the duration of dust effects would be permanent, potentially accumulating and persisting over the life of the mine and remaining at similar levels following mine closure; whereas the duration of erosion effects would range from temporary to long-term, with impacts potentially lasting for months or years until stabilization is achieved. The extent of soil disturbance, permafrost, and erosion effects would be local, as they would be limited to areas within the mine footprint and project property boundaries; whereas fugitive dust effects would range from local to regional, in that they could be measurable as far as 10 miles from the mine. The context of soil and permafrost effects would range from common, based on their regional distribution, to important, for those effects that are governed by regulation (e.g., erosion). Net overall effects associated with the mine site would range from minor to moderate.

Impacts to soils from ground disturbances, permafrost degradation, erosion, fugitive dust, and contaminated sites at the transportation facilities under Alternative 2, as well as impacts from permafrost hazards on man-made structures, would range from low to high intensity, although the intensity for most effects would be reduced to low to medium intensity through reclamation or other mitigation (e.g., remediation preventing spread of existing soil contamination, or ORV access restrictions). Soil disturbances under Alternative 2 would result in the permanent alteration of a total of roughly 900 acres of surface soil and associated erosion and permafrost effects (where present), an extent considered mostly local as they would be limited geographically to areas within the footprints of the individual infrastructure components, although ORV use could extend beyond the immediate vicinity of the road. The duration of dust effects along the road would be permanent, potentially accumulating and persisting over the life of the mine and into post-closure; whereas the duration of erosion effects could range from temporary (e.g., several months) to permanent (e.g., ORV soil degradation). The extent of dust and contaminated sites effects would be local, as they would be limited to areas within the vicinity of individual facility footprints (e.g., dust on order of 1/10th mile from road). The context of soil and permafrost effects would range from common, based on their regional distribution, to important for those effects that are governed by regulation (e.g., erosion, contaminated sites). Net overall effects associated with the transportation facilities would range from minor to moderate.

Impacts to soils from ground disturbances, permafrost degradation, erosion, and contaminated sites along the pipeline ROW and associated facilities under Alternative 2, as well as impacts from permafrost hazards on the pipeline, would range from low to high intensity, although the intensity for most effects would be reduced to low to medium through effective design, reclamation, access limitations, or other mitigation. Soils and permafrost would be permanently altered in areas of medium to high intensity effects, although the duration of most effects following reclamation would range from temporary to long-term until stabilization criteria are met. Effects from contaminated sites on the project (e.g., at Farewell airstrip) would be temporary, lasting through construction only. Soil disturbances under Alternative 2 would impact a total of 8,350 to 14,100 acres, depending on the amount of additional ROW space needed in areas of challenging ground conditions. While the pipeline would cross several

regions of Alaska, the extent of soil disturbance, erosion, and contaminated sites effects would be considered local, as they would be limited to areas within the footprint or immediate vicinity of the ROW and individual infrastructure components. Indirect ORV erosion effects could range from local (discrete segments of ROW) to regional (potentially extending for miles beyond the ROW if used to access new areas). The geographic extent of permafrost effects would be localized along intermittent ice-rich areas, mostly occurring along the north flank of the Alaska Range. The context of soil and permafrost effects would range from common, based on their regional distribution, to important, for those effects that are governed by regulation (e.g., erosion, contaminated sites). Net overall effects associated with the pipeline would range from minor to moderate.

As discussed above, these effects determinations take into account impact reducing design features (Table 5.2-1 in Section 5.2) proposed by Donlin Gold and also the Standard Permit Conditions and BMPs (Section 5.3) that would be implemented. These are discussed in Section 3.2.3.2, and several examples are presented below.

Design features most important for reducing impacts to soils include:

- Features to limit permafrost impacts at the mine site such as excavation to bedrock beneath key structures where needed, such as the TSF abutment and parts of the toe of the WRF;
- Design of TSF liner includes allowance of differential settling due to permafrost and season ahead stripping and settlement;
- The TSF will include a relatively flexible, textured geomembrane liner (60 mil or 1.5 mm) that is expected to withstand freezing temperatures, sharp rocks, and anticipated settlement scenarios with an appropriate factor of safety and to minimize impacts from porewater seepage on groundwater quality;
- Approximately 68 percent of the total pipeline length would be constructed during frozen winter conditions to minimize wetland and soil disturbances from support equipment. Areas selected for summer or fall construction would be based on geotechnical, terrain, safety, and continuity considerations;
- Based on the proposed design, the WRF stability meets or exceeds industry design criteria under both static and pseudo-static (earthquake) loading conditions; and
- Construction would employ design measures to preclude extended soil compaction.

Standard Permit Conditions, BMPs, and mandated spill prevention and response plans most important for reducing impacts to soils are discussed above in Section 3.2.3, and some examples are presented below:

- Implementation of Stormwater Pollution Prevention Plans (SWPPPs) and/or Erosion and Sediment Control Plans;
- Development and maintenance of Oil Discharge Prevention and Contingency Plan (ODPCP), Spill Prevention, Control and Countermeasure Plan (SPCC), and Facility Response Plan (FRP);
- Use of BMPs such as watering and use of dust suppressants to control fugitive dust; and

- Preparation and implementation of a Stabilization, Rehabilitation, and Reclamation Plan.

3.2.3.2.7 ADDITIONAL MITIGATION AND MONITORING FOR ALTERNATIVE 2

The Corps is considering additional mitigation (Table 5.5-1 in Section 5.5) to reduce the effects presented above. These additional mitigation measures are discussed above in section 3.2.3 and some examples include:

- Additional investigation should be considered prior to pipeline construction to map the specific location of potential contaminated soils at the Farewell airstrip (all alternatives), North Foreland barge landing (Alternative 3B only), Tyonek-Beluga pipeline trench segment (Alternative 3B only), and Puntilla airstrip (Alternative 3B only) compared to final grading plans, so that disturbance of these soils can be avoided if possible, and the level of effects reduced to low likelihood and intensity;
- WRF design criteria and plans for excavation at the WRF incorporate assumptions with regard to depth of permafrost. Seismic analysis of the WRF indicates the possibility of instability in the event that liquefiable ice-rich soils are present beneath the WRF deeper than is currently known. If fine-grained and/or ice-rich soil conditions are present deeper than expected, the stability of the soils as they thaw is uncertain and could result in high intensity effects downgradient in the event of WRF deformation or slope failure (Section 3.2.3.2.3). Further investigation and revised seismic stability analysis of the WRF design criteria and plans for excavation at the WRF toe should be considered to determine if deeper liquefiable materials exist and would require additional excavation during site preparation;
- The season of final pipeline termination and reclamation activities is not specified in current pipeline plans (SRK 2013b). To the extent practicable, closure activities should occur during the winter season (similar to construction) to minimize surface disturbances to soil and erosion potential;
- Promote salvaging and re-spreading topsoil over the overburden piles and allowing native vegetation and native seed planting vegetation growth to keep topsoil viable until it is needed during final reclamation. In pipeline reclamation practices, segregate windrowed organic soils as cover material (where present). Unless this material comes from the existing topsoil, it should not be used on the top of the trench as subsoil has no viable seed or other organic matter. Good construction practices include taking time to blade the layer of topsoil before trenching the pipeline;

If these mitigation measures were adopted and required, the summary impact rating for the mine site, transportation facilities, and pipeline ROW would remain minor to moderate.

The Corps is also considering the following additional monitoring:

- Monitoring of bank erosion upstream and downstream of Angyaruaq (Jungjuk) Port and consideration of streambank protection as part of an adaptive management plan, if warranted. This may include installation of geotextile matting, riprap armoring or methods from ADF&G's Streambank Revegetation and Protection Manual (Walter et al. 2005) to reduce the effects of eddy formation, scour, and bank erosion during flood events (BGC 2014e).

- The need for monitoring and rehabilitation in post-closure should be addressed in the revised SRR Plan prior to closure, and additional bonding should be considered to cover these activities.

3.2.3.3 ALTERNATIVE 3A – REDUCED DIESEL BARGING: LNG-POWERED HAUL TRUCKS

3.2.3.3.1 SOIL DISTURBANCE/REMOVAL

Mine Site

Effects on soil disturbance/removal under Alternative 3A would be the same as discussed for Alternative 2 for the mine site component, as facility footprints would be identical between alternatives.

Transportation Facilities

The reduction in barging associated with Alternative 3A would reduce effects associated with Kuskokwim River bank soils due to potential disturbances at relay points along the river. During rare low water barging periods, temporary barge moorage along the riverbank may be required at relay points to accommodate reduced barge tows or loads for transit conditions (i.e., draft depth). Temporary riverbank moorage alternatives may include infrequent access to soils above the river bank for rigging securement. Rigging securement would preferably use non-intrusive methods; however, minimal soil disturbances may be required on a case-by-case basis. Under Alternative 3A, the reduction of barge traffic by about one-third of the level under Alternative 2 nearly eliminates the need for barge travel during low water conditions to meet cargo and fuel shipping requirements at the mine site. Thus, potential soil disturbances at the relay points would range from negligible to low intensity, occurring very infrequently.

The reduction in fuel trucking along the mine access road under Alternative 3A would result in a slight reduction in dust effects from the mine access road which, like Alternative 2, are expected to be low intensity due to concentrations in dust similar to baseline.

Because the Bethel and Dutch Harbor ports would not require as much expansion, if any, under Alternative 3A, total soil disturbances could be reduced by about 10 to 20 acres. There would be a related reduction of permafrost degradation at the Bethel port. However, this is a small amount compared to overall soil disturbances for transportation infrastructure (about 900 acres), and the range of effects would be the same as Alternative 2, that is, low to high intensity from minor grading to blasting, with some reductions to medium intensity through reclamation (Section 3.2.3.2.1).

Natural Gas Pipeline

Effects on soil disturbance/removal under Alternative 3A would be the same as discussed for Alternative 2 for the pipeline component, as facility footprints and pipeline route would be the same as Alternative 2.

3.2.3.3.2 PERMAFROST

Mine Site

Anticipated effects on permafrost for the mine site under Alternative 3A would be the same as those described under Alternative 2.

Transportation Facilities

Permafrost does not occur in the Dutch Harbor area, and is unlikely to occur at the Kuskokwim River relay points due to the likely presence of a thaw bulb close to the river. The reduction of fuel storage expansion at the Bethel dock under Alternative 3A could reduce the extent of permafrost effects by several acres if permafrost is present. However, the rating for intensity of effects from Alternative 3A would be the same as Alternative 2 due to the need for the cargo terminal at Bethel; that is, medium intensity effects if thaw unstable soils are present and if not mitigated through excavation or special design.

Natural Gas Pipeline

Impacts to permafrost associated with the pipeline component of Alternative 3A would be the same as discussed under Alternative 2.

3.2.3.3.3 EROSION

The types of erosion impacts and mitigative ESC measures under Alternative 3A are expected to be the same as those described under Alternative 2 for the mine site, transportation facilities, and pipeline. While less upland soils and riverbank areas would be subject to erosion at transportation facilities under Alternative 3A, these areas are small compared to the project as a whole. Intensity levels for erosion at remaining project components would be the same, and like Alternative 2, the extent of impacts would be localized within the immediate vicinity of the remaining component footprints.

3.2.3.3.4 SOIL QUALITY/CONTAMINATED SITES

Contaminated sites conditions, and activities that cause fugitive dust impacts on soil quality, would be the same under Alternative 3A as Alternative 2. Thus, direct and indirect effects would be the same as described for Alternative 2.

3.2.3.3.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 3A

Effects at the mine site and along the pipeline from soil disturbance, permafrost degradation, erosion, and fugitive dust deposition under Alternative 3A would be the same as discussed for Alternative 2, as facility footprints and activities that create dust emissions would be essentially the same between alternatives. Impacts associated with climate change would also be the same as those discussed for Alternative 2.

Under Alternative 3A, there would be a small reduction in impacts to Kuskokwim River bank soils at relay points due to less low water travel, a reduction in soil and permafrost disturbance at ports by about 10 to 20 acres (out of a total of about 900 acres for the transportation facilities as a whole), and a slight reduction in fugitive dust from less fuel truck traffic on the mine access

road. Like Alternative 2, the intensity of effects for all transportation facilities under Alternative 3A would range from low to high intensity (e.g., minor grading to total removal), with some reductions to medium intensity through reclamation. Net overall effects would range from minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to soils would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required, the summary impact rating would remain similar to Alternative 2, minor to moderate.

3.2.3.4 ALTERNATIVE 3B – REDUCED DIESEL BARGING: DIESEL PIPELINE

3.2.3.4.1 SOIL DISTURBANCE/REMOVAL

Mine Site

With the exception of a reduced fuel storage capacity at the mine site, soil disturbance activities for Alternative 3B are generally the same as Alternative 2 for construction, operation, and closure. The decreased fuel storage capacity would likely reduce the required fuel storage footprint by roughly 75 percent in comparison to Alternative 2 (from 15 tanks down to four), resulting in roughly 10 acres less fuel storage under Alternative 3B at the mine site, although the site lies within the contiguous plant area and may be disturbed for other purposes (e.g., laydown). The reduction in fuel storage footprint under this alternative is small compared to overall soil disturbance areas for the mine site as a whole (roughly 9,000 acres).

Transportation Facilities

The area of soil disturbance at the Angyaruaq (Jungjuk) Port site would likely be similar under this alternative to that of Alternative 2, as fuel storage capacity would be needed at this site for the construction period. Thus, the site footprint would be similar to that of Alternative 2.

Expansion of the existing North Foreland Barge Facility dock in Tyonek under Alternative 3B would require soil disturbances during construction of a temporary barge landing adjacent to the dock to support dock extension and pipeline construction. The temporary barge landing area would disturb/compress an area of previously disturbed soils, and localized temporary fill placement may be necessary for barge off-loading. Soils in the barge landing area (mostly intertidal zone) may or may not require revegetation (upland soils are described below under Pipeline). Applicable Corps and ADEC permit stipulations would be followed for any fill placement. The anticipated intensity of effects to soil disturbances from this shoreline component would be of low to medium intensity (from minor disturbances/fill in area of previously disturbed soils), and would add a small amount of soil disturbance to those under the Alternative 2 transportation facilities (900 acres).

Diesel Pipeline

Soil disturbances for the diesel pipeline ROW include those described for Alternative 2, plus up to roughly an additional 700 acres for the construction ROW from Tyonek to Beluga, for a total of 12,200 acres for the whole construction ROW under Alternative 3B (Table 3.2-16). Cut and fill construction along the Tyonek-Beluga segment would be minimal due to low relief topography

in this area; thus, it is unlikely that the full construction ROW would be disturbed. Soil types in this area (Figure 3.2-6 and Table 3.2-7) consist primarily of peat, silt loam, loess, glacial till, and alluvium that are common in the Cook Inlet region of Alaska.

Table 3.2-16: Soil Disturbance Comparisons for Pipeline Alternatives

Soil Disturbance Estimates ¹	Alternative 2 (Proposed Action)	Alternative 3B (Diesel Pipeline)	Alternative 6A (Dalzell Gorge)
Surface Disturbance Length (miles)	315	334	313
Potential Construction ROW Surface Disturbance (acres) ^{2,3}	11,500	12,200	11,300
Off-ROW Soil Disturbance (acres)	2,600	2,800	4,100
Total ROW + Off-ROW (acres)	14,100	15,000	15,400

Notes:

1. Comparisons are for total pipeline routes, including alternate segments in Beluga-Tyonek area and Alaska Range (SRK 2012i, 2013b; Polaris 2014).
2. For maximum 300-foot wide construction ROW.
3. Areas not reduced by undisturbed soils above potential horizontal directional drilling (HDD) segments in Alaska Range. Alternative 6A would include 2.3 miles of HDD through Dalzell Gorge and under Happy River. Alternative 2 (and 3B) may include HDD and/or deep bedrock trenching along Threemile Creek/Jones River portion; length(s) and construction technique(s) to be determined in later design phase (Fueg 2014).

Soil disturbances at off-ROW facilities under Alternative 3B would be roughly 200 acres higher than Alternative 2 to accommodate three additional new Hercules-capable airstrips (at Puntilla, Tatlawiksuk, and George River) required to support potential oil spill response (OSR) activities; as well as an uplands facility near the North Foreland dock consisting of an operations center, fuel storage area, living quarters, OSR warehouse, and access road (Figure 2.3-39) (Polaris 2014). Some cut and fill may be required to construct at least one of the airstrips (George River). Gravel and concrete foundations would be required at the North Forelands tank storage area.

The types of construction used in the additional ROW and off-ROW areas under Alternative 3B would be similar to that of Alternative 2, and would affect relatively small additional areas compared to overall soil disturbances under Alternative 2. Thus, the intensity of effects would be similar to Alternative 2 (i.e., ranging from low to high, with reductions achieved through reclamation to low to medium intensity levels). The additional soil disturbance impacts under Alternative 3B would be localized within the pipeline component footprints. The duration of soil disturbances at some off-ROW facilities, such as airstrips and shoofly roads that would remain in usable condition during operations to support spill response needs, would be longer term than under Alternative 2, and beneficial effects of reclamation at these facilities would be delayed until the closure period. Specific infrastructure remaining during operations would be finalized during preparation of the spill response plan.

3.2.3.4.2 PERMAFROST

Anticipated effects on permafrost for the mine site, transportation facilities, and pipeline components under Alternative 3B would be the same as those described under Alternative 2. Geotechnical investigations and available information indicate that the area along the additional 19-mile segment of pipeline from Tyonek to Beluga is free of permafrost (Section 3.2.2.3.2).

Similarly, the diesel pipeline response to permafrost-related ground deformation is expected to be comparable to that described for the natural gas pipeline. Like Alternative 2, the temperature of the diesel would be within a few degrees of ambient ground conditions. The pipeline is not expected to freeze surrounding soils, and any thaw settlement would be more attributable to clearing and surface disturbances than product-induced thaw (Michael Baker Jr. 2013a). Thus, thaw settlement estimates would be similar to those described under Alternative 2 (Section 3.2.3.2.2).

3.2.3.4.3 EROSION

The types of erosion impacts and mitigative ESC measures under Alternative 3B for the mine site, transportation facilities, and pipeline are expected to be the same as those described under Alternative 2. While a larger soil area would potentially be subject to erosion under Alternative 3B, the intensity levels would be the same, and extent of impacts would be localized within the immediate vicinity of the component footprints.

3.2.3.4.4 SOIL QUALITY/CONTAMINATED SITES

Mine Site

Effects on soil quality from fugitive dust and existing contaminated soils at the mine site under Alternative 3B would be the same as Alternative 2.

Transportation Facilities and Diesel Pipeline

Effects on soil quality from mine access road dust under Alternative 3B would be the same as Alternative 2. Impacts from existing contaminated site conditions at or near the transportation and pipeline facilities are primarily the same as Alternative 2; however, additional conditions exist. Six open contaminated sites are present within about a ¼ mile of the ROW between the existing Tyonek dock and Beluga (Figure 3.2-9 and Table 3.2-10). The nature of contaminants at these sites is related to petroleum hydrocarbons present in soil and/or groundwater. In addition, petroleum-contaminated soils are reported at the FAA Puntilla Lake Station, which may coincide with the Puntilla airstrip proposed for use under Alternative 3B (Polaris 2014).

The contaminated site near the Tyonek dock is listed in the ADEC Contaminated Sites database as partly “open” and partly “cleanup complete.” While the site is located about ¼ mile southwest of the dock, depending on the size of the Alternative 3B temporary barge landing site, it is possible that soil disturbances during barge landing could encounter contaminated soils.

Most of the contaminated sites in the Beluga area are unlikely to impact soil conditions along the ROW based on the nature of the releases and general groundwater flow direction. Groundwater in the Beluga area is generally shallow, reported at 13 feet below ground surface, and the local direction of flow is generally to the east, which is opposite of the proposed pipeline corridor located to the west of most open sites. Of 3 sites where institutional controls exist in the Beluga area, no offsite migration of contaminants has been reported (ADEC 2013a). However, because one of the open sites is located upgradient of the ROW and three are very close to it, it is possible that soil disturbances during trenching could encounter contaminated soils.

In the event that contaminated soils are encountered at the above sites, the type and level of effects would be similar to those described in Section 3.2.3.2.4 for Dutch Harbor (i.e., likely localized, low to medium intensity), with responsibility for remediation being that of the landowners/operators. Mitigation recommendations are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation, for additional investigation at the Tyonek barge landing site, Beluga area ROW, and Puntilla airstrip prior to pipeline construction to map the specific location of potential contaminated soils compared to final construction plans, so that disturbance of these soils can be avoided if possible, and the level of effects reduced to low likelihood and intensity.

3.2.3.4.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 3B

Effects at the mine site and the transportation facilities from soil disturbance, permafrost degradation, erosion, and fugitive dust under Alternative 3B would be the same as discussed for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. The small decrease in fuel storage footprint under Alternative 3B lies within the contiguous plant area, and is likely to be disturbed for other purposes (e.g., laydown). Additionally, the small increase in soil disturbance at the North Foreland port would be in an area of already disturbed soils, and would not change the range of impacts and overall effects from those of Alternative 2. There could be a small increase in contaminated soils encountered during construction near the Tyonek dock. Net overall effects for the mine site and transportation facilities would range from minor to moderate.

Up to an additional 900 acres of soil would be disturbed under Alternative 3B associated with the pipeline due to the increased length of ROW and associated facilities. There would be no change in permafrost effects (no permafrost between Beluga and Tyonek), and erosion effects would occur and be managed at the same levels of intensity as those under Alternative 2. There could be an increase in contaminated soils encountered during construction in the Beluga-Tyonek area and at Puntilla airstrip. Net overall effects would range from minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to soils would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required, the summary impact rating would remain similar to Alternative 2, minor to moderate.

3.2.3.5 ALTERNATIVE 4 – BIRCH TREE CROSSING (BTC) PORT

3.2.3.5.1 SOIL DISTURBANCE/REMOVAL

Mine Site

Soil disturbance/removal effects for the mine site under Alternative 4 would be the same as described under Alternative 2.

Transportation Facilities

Soil disturbance impacts associated with transportation components that are different under Alternative 4 as compared to Alternative 2 are described below.

BTC Mine Access Road and Port: The 73-mile long BTC Road would be about 43 miles longer than the mine access road under Alternative 2, or 2.43 times longer. The total estimated area of soil disturbance/removal associated with the road is approximately 900 acres, which is more than three times that of the mine access road under Alternative 2. The BTC Port would occupy a footprint of about 65 acres, more than twice the size of the Angyaruaq (Jungjuk) Port under Alternative 2.

Alternative 4 would employ similar port and road construction techniques as those described for Alternative 2, as well as similar maintenance and post-mine disposition. Like Alternative 2, soil disturbance during construction of the BTC Road and Port would result in localized, noticeable to obvious changes in soil cover (medium to high intensity effects), which would be partly reduced through reclamation. Gravel fill construction would be used over approximately 75 percent of the alignment, and the remaining 25 percent (roughly 20 miles) would use cut and fill construction methods, which is slightly longer than cut and fill lengths for the mine access road. In most circumstances, fill would range from 3 to 5 feet thick, and be placed over a generally thin surface layer of organic mat and peat, which is prevalent along most surfaces of the alignment. Geofabric would be placed along approximately 26.5 miles of the alignment in addition to 3 miles of geogrid, primarily in permafrost and wetland areas (Section 3.2.3.5.3).

As in Alternative 2, port construction at BTC would require disposal of approximately 10,000 cy of dredge materials derived from development of shoreline infrastructure (sheetpile wall and berthing). All dredge materials would be used as reclamation media for material borrow sites. For this reason, no additional soil disturbances are associated with dredged materials.

Effects from operations and closure activities for the BTC Road and Port are generally the same as those described for Alternative 2. Approximately 1,200 cy of dredge materials generated annually from berth maintenance activities would continue to be placed in material borrow sites as reclamation material.

Soil map units that would be impacted from construction activities along the BTC Road and Port are shown on Figure 3.2-1 and listed in Table 3.2-3. More than 90 percent of areas disturbed by road and port construction would impact map units associated with colluvium and frozen loess along low mountains and glaciated uplands. These soil types are regionally prevalent, extending well beyond the proposed alignment corridor. Less prevalent soil types within the construction corridor, but also regionally common, include those associated with alluvium in floodplains and terraces.

Temporary Ice Road: Simultaneous construction of the BTC Port Road from opposing ends would require the development of a single-season temporary ice road from Crooked Creek village to the mine site along Crooked Creek valley for a distance of about 12 miles. Ice roads are commonly used in arctic and sub-arctic environments for overland transport of heavy loads and are intended to minimize physical and thermal impact to underlying vegetation or tundra. Established guidelines exist for ice roads constructed on state and federal lands, and include permitting and planning processes that can involve multiple regulatory agencies and restrict travel to a limited time in late winter.

Impacts to soils from ice road construction could occur through vegetation degradation and runoff, depending on slope angle. Minimal disturbance to surface vegetation can be achieved when using methods following state and federal management practices. Previous studies on the North Slope of Alaska have shown that complete recovery of vegetation is attainable within a 24-year period for a single-season ice road (BLM 2005b). More recent improvements in BMPs

that can minimize vegetation and soil impacts include ice road route selection (landscape characteristics), construction methods, equipment operators, and period of use (one season versus consecutive season usage) (ADNR 2010). Based on limited information on permafrost conditions at the BTC Port, the anticipated levels of effect are expected to be of low to medium intensity

In general, upland vegetation and soils are more sensitive to ice road construction than wetlands, and impacts generally decrease with increased surface moisture content/saturation (ADNR 2010; BLM 2005). While wet soils are generally more resilient and better suited for ice road construction, increased slope gradients in these conditions can facilitate erosion (Kidd 2010). More than 90 percent of the ice road alignment under Alternative 4 is located within soil map units that represent alluvium and colluvium along floodplains, terraces, and lower slopes of Crooked Creek valley (Figure 3.2-1). Vegetation types associated with these soils (e.g., taiga, scrub, forest) are not ideal with respect to ice road construction impacts. The anticipated intensity of effects is expected to be low to medium, in that they may or may not be noticeable. Although the potential for long-term localized soil degradation exists, the short single season of use would minimize long-term surficial impacts.

Kuskokwim River Corridor: The BTC Port Site would reduce barge travel distances along the Kuskokwim River by approximately 25 percent in comparison to Alternative 2. In doing so, several critical sections upstream of the BTC Port (Aniak, Holokuk, Upper Oskawalik), where barges would need to be relayed during low water periods, would be avoided (AMEC 2014). Like Alternative 2, the intensity of soil disturbance effects from relay activities at the Nelson Island critical section below BTC Port are anticipated to be of low intensity from infrequent minor soil compaction.

Natural Gas Pipeline

Soil disturbance/removal impacts associated with the pipeline under Alternative 4 would be the same as described under Alternative 2.

3.2.3.5.2 PERMAFROST

Mine Site

Permafrost effects for the mine site under Alternative 4 would be the same as described under Alternative 2.

Transportation Facilities

Permafrost impacts associated with transportation components that are different under Alternative 4 as compared to Alternative 2 are described below.

BTC Mine Access Road: Permafrost was encountered in about two-thirds of geotechnical borings drilled along the BTC Road alignment (Recon 2007b), which extend along roughly 40 to 50 miles of the road corridor, although substantial visible ice is only present in a limited number of borings located in the Owhat River drainage, and intermittently from the east side of Tor Creek to the road terminus at the BTC Port. Field observations also report thermokarst terrain along this road corridor, which inconsistently coincides with visible ice in soil borings. Prominent thermokarst terrain was observed immediately west of the Iditarod River; and limited segments

were observed in the Cala Poco Creek area, west of Cobalt Creek, west of the Lithos Creek floodplain, east of Kaina Creek, at Tor Creek flats, and Aurum Creek flats. Much of the permafrost along the BTC Road alignment appears to be associated with thaw stable soil conditions; however, multiple segments of the alignment contain thaw unstable silt. Permafrost conditions in this area are predominantly warm (31° to 32° Fahrenheit) based on studies performed at the mine site, adding to the likelihood of thaw degradation when soils are disturbed.

Impacts to permafrost from the BTC Road would be similar to those described for the mine access road proposed under Alternative 2, with several notable differences in the intensity and extent of impacts. The levels of effects would range from low intensity in thaw stable soils, to medium to high intensity in thaw unstable soils and thermokarst terrain, in that thaw settlement during operations and beyond would likely require more frequent maintenance and fill repairs than the mine access road. The use of geotextile reinforcement along some road segments is expected to be effective in minimizing road surface deformation and embankment sloughing from thaw settlement (e.g., Alfaro et al. 2006) and reduce most effects to low to medium levels, although isolated areas requiring multiple fill repairs over time could remain. The extent of thaw unstable soil conditions are greater along the BTC Road alignment; therefore, the potential for thermal degradation and associated effects are likely to be greater, although impacts would still be localized within the immediate vicinity of the road footprint. The duration of impacts would range from long-term (e.g., subsidence repaired over several years) to permanent, since permafrost degradation is not expected to recover, and the road would remain in perpetuity to support monitoring and water treatment at the mine site.

BTC Port Site: Limited geotechnical information is available for the BTC Port. The closest borings to the port, located about ½ to 1 mile northeast of the port site along the BTC Road encountered both frozen and unfrozen silt, which suggest a range of conditions could be present at the port site, ranging from no permafrost to thaw unstable permafrost. Frozen soils in these borings contain up to 10 percent visible ice. No thermokarst terrain was noted as coinciding with the BTC Port terminus. These discontinuous permafrost conditions are similar to the Angyaruaq (Jungjuk) Port under Alternative 2. About one-third of borings at the Angyaruaq (Jungjuk) Port site contain permafrost with substantial visible ice (up to 50 percent) in similar soil types. In addition, active thermokarst and ongoing thaw degradation was observed in the vicinity of the Angyaruaq (Jungjuk) Port. NRCS soil types that are generally associated with common permafrost are present at both BTC and Angyaruaq (Jungjuk) ports.

Based on limited information on permafrost conditions at the BTC Port, the anticipated levels of effect are expected to be of low to medium intensity, with effects likely to be reduced to low intensity through typical planned mitigation in design and construction practices, such as further geotechnical investigation and possible permafrost excavation if needed.

Temporary Ice Road: Although no detailed permafrost studies have been performed along the Crooked Creek temporary ice road alignment, permafrost occurrence and distribution is likely similar to that documented at the mine site near Crooked Creek, where discontinuous permafrost is common (Figure 3.2-2). Permafrost thaw from ice road construction (if any) could occur from compaction or degradation of insulative surficial organic materials. North Slope case studies indicate that increases in thaw depth of several inches can occur along ice roads, but with little visible change in existing thermokarst features where slow vegetation recovery exists (Kidd 2010).

Although the potential for permafrost impacts exists from ice road construction, effects would likely be of low to medium intensity (in that they may or may not be noticeable) if construction methods incorporate state (ADNR) and BMPs applicable to the selected route, and no inadvertent scraping of vegetation occurs. Any permafrost degradation from construction is likely to be undifferentiated from naturally occurring processes. Effects are expected to be temporary to long-term in duration, depending on the rate of vegetation recovery.

Natural Gas Pipeline

Permafrost effects for the mine site under Alternative 4 would be the same as described under Alternative 2.

3.2.3.5.3 EROSION

Mine Site

Erosion effects for the mine site under Alternative 4 would be the same as described under Alternative 2.

Transportation Facilities

Erosion impacts associated with transportation components that are different under Alternative 4 as compared to Alternative 2 are described below.

BTC Mine Access Road and Port: Like the soil types along the mine access road under Alternative 2, erosion ratings for soil types along the BTC Road and port range widely, from slight to severe for both water and wind erosion (Table 3.2-3). Culverts and bridges installed at stream crossings and other drainages along the road are expected to be largely effective in controlling runoff and stream bank impacts that would otherwise lead to erosion. Anticipated erosional effects and construction activities along the BTC Road would be similar to those described under Alternative 2, except that there would be longer road sections along slopes requiring cut and fill construction, greater thermal erosion potential, and more major stream crossings requiring bridges under Alternative 4, which would generally require more robust ESC measures, monitoring, and maintenance to manage erosion effects. Potential erosion effects from waste soils generated during berth excavation at the BTC Port could potentially be less than that of Alternative 2, as these materials are proposed to be used in material site reclamation, as opposed to construction of a waste soil stockpile under Alternative 2.

Due to the presence of organic-rich surface soils and frozen soil conditions along the potential BTC alignment, and the closer proximity of the port to population centers (e.g., Aniak), the potential for soil degradation in the event of ORV usage is likely along numerous segments. Degradation might include increased erosion and soil displacement (gullyng, churning and rutting), compaction, damage to supporting vegetation and sustainability; changes to the surface water flow regime, and permafrost degradation (Loomis and Lieberman 2006).

Like Alternative 2, the intensity of erosion effects for the BTC Road and Port under Alternative 4 are expected to be managed at low to medium levels of intensity through the use of BMPs and ESC design features. Other than bridges and culverts, specific ESC details or stabilization measures have not been specified for the road or road material sites (under either Alternative 2

or 4), but are expected to be addressed in final design as part of SWPPP permitting, and during final reclamation and closure planning.

Temporary Ice Road: As described above (Sections 3.2.3.5.1, Soil Disturbance/Removal and 3.2.3.5.2, Permafrost), ice roads can trigger erosion if vegetation and permafrost degrades, depending on runoff and slope gradient. Soil erosion effects associated with the temporary ice road under Alternative 4 are likely to be of low to medium intensity (in that they may or may not be noticeable) if appropriate management practices are followed and no inadvertent scraping of vegetation occurs. Effects would be localized within the immediate vicinity of the ice road corridor, and temporary to long-term in duration, depending on the rate of vegetation recovery.

Natural Gas Pipeline

Erosion effects for the pipeline under Alternative 4 would be the same as discussed under Alternative 2.

3.2.3.5.4 SOIL QUALITY/CONTAMINATED SITES

Mine Site

Soil quality and contaminated sites impacts for the mine site under Alternative 4 would be the same as described under Alternative 2.

Transportation Facilities

No documented contaminated sites exist in the vicinity of the BTC Road alignment or the Village of Crooked Creek. There would be about 10 fewer contaminated sites located along the Kuskokwim River as a result the shorter transportation corridor under Alternative 4 (Figure 3.2-4). There would be less potential for low intensity indirect effects from wave-induced shoreline erosion on contaminated sites.

The effects of dust on soil quality along the BTC Road are expected to be similar to those described for Alternative 2, that is, of low intensity due to metals concentrations in dust that are similar to baseline. While the analysis of dust impacts under Alternative 2 is based on rock samples collected along the mine access road (Section 3.2.3.2.4 and Figure 3.2-13) effects are expected to be similar along the BTC Road, as the area of greatest concern would be borrow sites in the eastern part of the BTC Road corridor shared by the mine access road corridor, where rock types are most similar to mineralized bedrock at the mine (Cretaceous sedimentary rock). Additional evaluation to confirm metals concentrations at material sites along the BTC Road would be completed in final design (Chapter 5, Impact Avoidance, Minimization, and Mitigation).

Natural Gas Pipeline

Soil quality and contaminated sites impacts for the mine site under Alternative 4 would be the same as described under Alternative 2.

3.2.3.5.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 4

Effects at the mine site and for the pipeline component from soil disturbance, permafrost degradation, erosion, and fugitive dust under Alternative 4 would be the same as discussed for Alternative 2.

For the transportation facilities under Alternative 4, the extent of soils and permafrost that would be permanently altered (total removal, buried by fill, thaw settlement) would cover about 40 more miles of road length and 39 more acres of port site than under the proposed action. While most impacts would be of low intensity with site-specific design, there could be localized medium to high intensity effects in thermokarst areas along the BTC road that could require repeated fill repairs over time. In addition, there could be low to medium intensity soil compaction and permafrost degradation effects (i.e., may or may not be noticeable) beneath 12 miles of ice road that would not occur under Alternative 2. Direct erosion effects would be managed at the same levels of intensity (due to SWPPPs and BMPs) as those under Alternative 2, although erosion at the BTC port site could be of lower intensity due to reuse of berth construction soils in material site reclamation. There would be less disturbance of riverbank soils due to fewer relay points along the Kuskokwim River under Alternative 4, and less potential for low intensity indirect effects from shoreline erosion on contaminated sites. Road dust effects on soil quality along the road would be similar to Alternative 2, as material site concentrations are expected to be similar to baseline. Indirect effects from ORV use of the BTC road would potentially be higher under Alternative 4 due to a higher occurrence of organic-rich and permafrost soils, and closer proximity to population centers. Impacts associated with climate change would be the same as those discussed for Alternative 2. Net overall effects for soils and permafrost under Alternative 4 would be moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to soils would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required, the summary impact rating would remain similar to Alternative 2, moderate.

3.2.3.6 ALTERNATIVE 5A – DRY STACK TAILINGS

3.2.3.6.1 SOIL DISTURBANCE

Mine Site

Disturbances to soil under the dry stack tailing alternative (for both Options 1 and 2) are slightly greater than those for Alternative 2; however, they are not considered to be drastically different. The overall soil disturbance footprint from the dry stack tailings alternative (both options) in the Anaconda Valley is approximately 2,461 acres, as compared to the Alternative 2 TSF that would impact 2,384 acres, or an increase of 77 acres (BGC 2014a).

Minor variations in soil disturbance quantities include additional areas associated with infrastructure requirements, and overburden stockpile acreage. An additional 8 acres would be required to accommodate a filter plant for tailings processing. Although an additional 8 acres would be disturbed from this infrastructure, the rock generated from construction activities would be appropriated for dam construction. Overburden stockpiles generated under this alternative would generate a slightly larger total overburden stockpile footprint. Alternative 5A

is anticipated to result in a slightly increased stockpile footprint of 45 acres, or a 12 percent increase from Alternative 2. Stockpiles would be similarly located, designed, and managed as those described under Alternative 2 (BGC 2014a).

More notable soil disturbance deviations from Alternative 2 would occur during the closure and reclamation phase of the operating pond, which represents approximately 40 percent of the TSF area under this alternative. The operating pond would be similarly constructed as the TSF impoundment under the proposed action. Unlike the proposed action, however, the operating pond water and liner would be removed once all off-spec tailings are pumped to the open pit, and the main dam and downstream face of the upper tailings dam regraded to 3H:1V slopes. Although soils would be disturbed during operating pond construction, with the exception of the reclaimed main dam, post-reclamation topography under the pond would more closely resemble pre-development landforms. The dry stack landform remaining in the post-closure period under Alternative 5A would be situated higher in the valley and reach a higher final elevation (950 feet) than the remaining landform under Alternative 2 (830 feet), which would cover the entire TSF footprint.

Under this alternative, tailings would be dewatered to produce a filter cake that is trucked, spread, and compacted in controlled lifts on the drystack. Reclamation of the dry stack would include grading to establish positive drainage and an LLDPE liner incorporated into the closure cover (BGC 2015d, 2015e). Like Alternative 2, reclamation of the dams would include placement of overburden and slope flattening.

While BGC (2014a) does not detail how the ground surface beneath the operating pond would be reclaimed after liner removal, it is assumed that the same methodology used for the dams and other reclaimed soil surfaces would be employed (Section 3.2.3.2.1, Mine Site – Closure, Reclamation, and Monitoring).

Since disturbed soil acreages under this alternative are comparable to the proposed action, the same effects on soil are anticipated. Although the reclaimed operating pond landscape would more similarly resemble the pre-construction landscape, surface soils would still have to be stripped to accommodate operating pond construction and would result in permanent alteration of soils. For this reason, there would be minimal soil disturbance differences between Alternative 5A and Alternative 2.

Transportation Facilities and Natural Gas Pipeline

Soil disturbance/removal impacts associated with the transportation facilities and natural gas pipeline components of Alternative 5A would be the same as described under Alternative 2.

3.2.3.6.2 PERMAFROST

Mine Site

Disturbances to permafrost during construction of the TSF would be similar to the proposed action with minor exceptions. Although the dry stack impoundment area would not require installation of a liner under Option 1, excavation of ice-rich overburden would be required to prevent excessive thaw-induced slope deformation under either option (BGC 2014a). The quantities of stripped thaw unstable, ice-rich overburden removed during construction of the operating pond and dry stack impoundment areas would be similar to the proposed action,

based on similar acreages of disturbance. The volume of ice-rich overburden excavated to bedrock beneath the upper and main dams, however, could be greater under this alternative, due to the larger combined dam footprints. Modified underdrains and permanent overburden pressure would likely result in comparable permafrost degradation below the dry stack impoundment area during operation and throughout post-closure (in perpetuity). For this reason, the duration of eventual disturbances to permafrost under this alternative are expected to be similar to those described for the proposed action (permanent).

Transportation Facilities and Natural Gas Pipeline

Permafrost effects for the transportation and natural gas pipeline components under Alternative 5A would be the same as described under Alternative 2.

3.2.3.6.3 EROSION

Mine Site

Construction

Erosion during the construction phase would be mostly similar between Alternatives 2 and 5A (both options) based on the following:

- The TSF is located in the Anaconda Valley in generally the same footprint and acreage as the proposed action.
- Similarly timed seasonal construction stages will incorporate a variety of similar construction methodologies and design features as the proposed action. This would include water management practices that incorporate fresh and contact water diversion channels, and overburden stockpile design and management.
- Removal of ice-rich overburden would be required to prevent thaw-induced slope deformation and related erosion throughout most of the operating pond and dry stack footprint.
- Erosional processes and mechanisms would be the same as Alternative 2 (i.e., hydraulic and wind); however, these processes could result in different erosional outcomes based on physical property differences at the time of tailings deposition (dry versus slurried). At a minimum, plans and programs related to control and mitigation of erosion at the mine site throughout construction to closure activities would also be the same as Alternative 2.
- Existing soil types and corresponding erosional susceptibilities would also be the same as the proposed action since both alternatives generally share the same TSF footprint.

Operations and Maintenance

Notable differences during operations that could result in different erosion effects between Alternatives 2 and 5A include the following:

- Unlike the proposed action where the entire TSF would be lined, the lack of a liner beneath the dry stack could conceivably result in increased suspended sediment in subsurface flow. It is estimated that collection of TSF-affected water at the end of

operations and throughout closure would be 53 percent higher than the proposed action. However, the dam filter zones and geotextile wrapping around underdrains are expected to keep sediment from moving downgradient.

- Overburden generated from TSF construction would result in a 12 percent increase in overburden stockpile volume (45 acres) compared to the proposed action. The increased volume would increase the potential for erosion; however, similar design and erosion mitigation features would likely result in no appreciable erosional differences.
- Hydraulic and wind erosion at the TSF (dry stack) would be more prevalent during the operational period under Alternative 5A in comparison to the proposed action. This is largely attributed to an increase in the amount of sloped topography, increased dry stack surface area exposed to erosional processes, and limited opportunity for progressive reclamation during operation. Exposed surfaces subjected to erosional processes would range from 220 acres after the first year of construction to 1,500 acres at the end of mine operation, which represent an increase of 47- to 60-percent above the area of the exposed tailings beach under Alternative 2.
- A variety of measures would be implemented to mitigate dry stack erosional processes:
 - Dewatering of tailings to within 3 percent of the optimum moisture content prior to placement to facilitate compaction to a minimum of 90 percent maximum dry density in 1-foot lifts;
 - Freshwater diversion channels constructed around the perimeter of the dry stack in three separate phases as the elevation progressively increases with continued tailings deposition. Diversion channels would be constructed to minimize erosion and improve surface flow efficiency;
 - Grading and sloping of dry stack surfaces to the south to minimize surface infiltration. Sloped dry stack surfaces would direct contact water to a water collection channel located on the south face of the dry stack, and eventually discharge to the operating pond;
 - Silt fencing along inactive dry stack surfaces to reduce hydraulic and wind driven erosional processes;
 - Management of snow clearing practices during winter months to minimize exposed dry stack surfaces; and
 - Aerial application of polymer dust suppression and soil stabilizer solutions on the entire dry stack surface for every 3-foot rise in tailings deposition. Although no specific polymer has been selected for use, a potential equivalent includes Entac Dust Control and Soil Stabilizer Solution by KBM Resources® for comparative purposes. The polymer is an organic, tall oil pitch emulsion that is a non-toxic, non-corrosive, non-water soluble compound used for a variety of dust control and surface stabilization applications. During periods of high wind conditions, however, erosion could occur during tailings placement between polymer applications. Additional discussion of fugitive dust issues is presented in Section 3.2.3.2.4.

- In general, the above ESCs and BMPs are more complex than erosion control required under Alternative 2, and may be more difficult to manage during periods of high winds or rainfall.
- Potential dry stack instability during operations could cause related erosion concerns. Conditions that could result in instability include inadequate tailings dewatering, unsuitable compaction of tailings, and variable moisture contents within the dry stack. Deposition of tailings during winter months would include frozen lifts of material that may result in inadequate compaction, or increased pore pressure and subsequent liquefaction potential when thawed. Furthermore, mounding of groundwater within the dry stack is expected, some of which could occur as small individual perched water layers between lifts. Water table mounding is expected to have a limited effect on dry stack stability, however, due to bottom-up construction in controlled lifts (BGC 2014a). Additional discussion regarding dry stack instability issues is presented in Section 3.3, Geohazards and Seismic Conditions.

Closure, Reclamation, and Monitoring

Erosion associated with closure of the dry stack could be less than the proposed action for the following reasons:

- Both alternatives would require a closure cover area of approximately 2,500 acres; however, the dry stack would support vehicle traffic upon completion for cover placement.
- The dry stack alternative is estimated to require approximately one-sixth the earthwork effort of the proposed action in a much shorter time period. Comparatively reduced material handling and expedited closure proceedings would result in a diminished erosion potential.

Restoration measures under Alternative 5A that are similar to Alternative 2 include the following:

- Completed surfaces would eventually direct surface runoff via a spillway to Crevice Creek after Year 10 of closure.
- Surface runoff during the reclamation process (5 years), and for an additional 5 years thereafter, would be directed to a new SRS established downstream of the upper dam, and eventually to the open pit.

Reclamation of the dry stack would include an LLDPE liner incorporated into the closure cover to provide for minimum potential infiltration into the dry stack. The LLDPE has a saturated hydraulic conductivity of 3.0×10^{-13} cm/s (BGC 2015d, 2015e). While this is potentially more protective of the environment because of reduced seepage flow (discussed in Section 3.3, Geohazards), placement of a protective layer of soil on top of the cover could result in more erosion control issues than that of the engineered soil cover for the TSF under Alternative 2.

It is also possible that increased activity involved in removing the operating pond would increase erosion. After water and off-spec tailings from the operating pond are pumped to the open pit, the liner would be removed, and the main dam and downstream face of the upper dam regraded to 3H:1V slopes. An interim sediment pond may be required to address suspended sediment issues during vegetation establishment on reclaimed surfaces.

Summary of Mine Site Impacts

Comparison of erosional impacts between Alternative 5A and the proposed action indicates similar conditions during the construction phase; increased erosion potential during the operational phase; and both reduced and increased erosion potential during closure at the dry stack and operating pond, respectively. Although some effects would likely offset each other, erosional increases inherent to the operational phase from the large exposed dry stack surface area, together with the general increased complexity of earthwork activities at the TSF under Alternative 5A, are anticipated to result in a net increase in the intensity of erosion effects.

Like Alternative 2, the intensity of effects in most areas of the mine site would range from medium to high intensity if uncontrolled, with BMPs expected to result in most effects being low to medium intensity. However, because the size of the dry stack is unprecedented, there would be an increased difficulty in controlling wind erosion in particular, potentially resulting in intermittent high intensity effects (i.e., effects in which planned BMPs and ESC measures are unsuccessful). The duration of effects would range from temporary to long-term, e.g., intermittent wind erosion from the dry stack could continue over years, but effects would be shorter in closure due to more favorable conditions resulting in less earthwork. The geographic extent of erosion effects would be local, assuming planned dust control mitigation measures are effective in limiting dust dispersion. However due to the higher position of the dry stack relative to surrounding topography, wind erosion would likely be greater under Alternative 5A than Alternative 2.

Transportation Facilities and Natural Gas Pipeline

Erosion effects for transportation and natural gas pipeline components under Alternative 5A would be the same as described under Alternative 2.

3.2.3.6.4 SOIL QUALITY/CONTAMINATED SITES

Mine Site

Soil quality impacts under Alternative 5A are comparable to those of Alternative 2, with the exception of fugitive dust. It is anticipated that tailings under Alternative 5A (both options) would exhibit the same chemical constituents of concern in fugitive dust as those described for the proposed action (Section 3.2.3.2.4 and Table 3.2-12). There would be limited addition of reagents to the filtration process stream, primarily a flocculant used during the thickening process (BGC 2014a). The flocculant, known by the trade name Entac, is a tall oil pitch emulsion which is a by-product of pine tree pulping. Entac is non-lethal to aquatic organisms, naturally decomposes over a period of months, and is not expected to impact soil quality (Rieser 2015b).

Due to the quantity and nature of exposed tailings surfaces under this alternative, a greater potential for fugitive dust generation and dispersion is anticipated than under Alternative 2. Exposed surfaces (tailings) after the first year of operation for the dry stack alternative and the proposed action (TSF tailings beach) are 220 acres and 150 acres, respectively. Corresponding exposed surfaces for the dry stack alternative and the proposed action at the end of mine operation are 1,500 acres and 940 acres, respectively, a 60 percent increase for this facility under Alternative 5A. It is estimated that the increase in surface area and material handling under Alternative 5A would cause a 6.6 percent increase in total fugitive dust emissions at the mine

site over that of Alternative 2 for all sources combined (Rieser 2015b). This percent increase is less than the increase in surface area at the TSF, because other major sources of dust would not change under this alternative (e.g., pit).

Processed filter cake will have a reduced moisture content of 19.7 percent by mass (%m) to accommodate planned deposition and compaction practices (BGC 2014a). The reduced moisture content could potentially increase fugitive dust mobilization from wind in comparison to slurried tailings under the proposed action. Activities associated with the immediate transport and placement of dewatered tailings by heavy equipment are not likely to generate appreciable quantities of fugitive dust since placed materials exhibit some stickiness (cohesiveness) at 20%*m* (BGC 2014a). However, surfaces exposed for prolonged periods between successive lifts would be most susceptible to disturbances by heavy equipment and atmospheric conditions (i.e., desiccation, wind, etc.). These surfaces are most likely to result in fugitive dust generation during the operational period. Little if any fugitive dust is anticipated following TSF closure since exposed surfaces would be capped and reclaimed as described in Section 3.2.3.2.4. Variables that are likely to influence fugitive dust generation during mine operation include operational controls and mitigation measures, seasonal weather conditions (i.e., temperature, humidity, wind, precipitation), and concurrent reclamation activities (to the extent practicable).

Fugitive dust mitigation is anticipated throughout the TSF operational period. Fugitive dust effects are anticipated to be most intense during dry summer conditions (May to October), and least intense during April and winter months due to wet or frozen conditions. Potential mitigation measures to minimize fugitive dusts include wind breaks, snow removal activities, dust suppression, and to a lesser extent concurrent reclamation. Silt fence windbreaks along inactive dry stack surfaces would reduce erosion by hydraulic and wind driven processes. Snow clearing practices during winter months would be limited to active areas to minimize exposed dry stack surfaces. Most important, however, would be the application of polymer dust suppression and soil stabilizer solutions on dry stack surfaces. Polymers would be aerielly distributed over dry stack tailings surfaces following every 3-foot lift (BGC 2014a). Concurrent reclamation would reduce exposed dry stack surfaces and fugitive dust mobilization; however, this would be limited to the south- and west-facing slopes as the tailings raises advance.

While fugitive dust dispersion modeling has not been conducted for this alternative, transport mechanisms and metals concentrations are expected to be similar to those described for the proposed action. The concentration and extent of fugitive dust dispersion and deposition could be measurably greater than the proposed action, and could include an increase in the concentration and dispersion to the closest points of compliance in prevailing wind directions (Section 3.2.3.2.4), although the increase is expected to be relatively small in the context of other major sources of fugitive dust that would not change under this alternative. Additional discussion of impacts to air quality is discussed in Section 3.8, Air Quality.

Despite the potential for increased deposition (mass and extent) of fugitive dust in soils over the life of the mine, concentrations of mercury are likely to be below ADEC soil standards protective of direct contact and inhalation pathways for human health (see Section 3.12, Wildlife, for effects on biota). This is based on low levels expected in ore and tailings samples and corresponding ADEC soil standards (one to two orders of magnitude). For these reasons, mercury would continue to have a low intensity of effects under this alternative. The lateral extent of mercury deposition under this alternative is likely to be similar to that of the proposed

action (Figure 3.8-5 in Section 3.8 Air Quality), as dust emissions would be dominated by other major sources that would not change under this alternative.

At a minimum, concentrations of arsenic in soil from dust deposition would be similar to the proposed action, predicted to be about a 1 to 5 percent increase in soil concentration over the mine life. Compared to Alternative 2, arsenic could be slightly greater in concentration and extent outside the footprint of the dry stack based on assumed fugitive dust scenarios associated with this alternative, which predict about a 6.6 percent increase in dust compared to Alternative 2. Like Alternative 2, while the added arsenic in soils from dust falling outside of the footprint of the dry stack are likely to exceed both baseline and ADEC levels over the mine life and would remain in soils beyond closure, potential health effects are considered to be of low intensity (Section 3.22, Human Health).

Summary of Mine Site Impacts

Similar to the proposed action, impacts to soil would be of would range from low intensity (e.g., metals with low concentrations in dust that may or may not be measurable as elevated concentrations in soils) to medium intensity (e.g., arsenic-bearing dust deposition resulting in small increases in soil concentration exceeding naturally high baseline and ADEC levels protective of human health). Additional mitigation recommendations that could further the understanding of these effects on soil resources and other receptors are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation. Like Alternative 2, effects are expected to range from local to regional, extending from nearby watersheds within mine site property boundaries to as far as 10 miles away. A slightly broader distribution of soil impacts is possible under this alternative due to a small increase in the amount of dust (0.1 percent more than Alternative 2). Incremental effects compared to the proposed action would be small, as dust emissions at the mine site are dominated by major sources other than the dry stack (e.g. pit, roads, hauling) that do not change under this alternative. Soil impacts would be permanent, potentially accumulating and persisting over the life of the mine and beyond closure. Planned mitigation measures for the dry stack could be partially effective in controlling these effects.

Transportation Facilities and Natural Gas Pipeline

Soil quality and contaminated sites impacts for transportation facilities and the natural gas pipeline under Alternative 5A would be the same as described under Alternative 2.

3.2.3.6.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 5A

Under Alternative 5A (both options), there would be a slightly greater area of soil disturbance (about 85 acres more than Alternative 2 for TSF and filter plant) and permafrost removal beneath dams (due to their larger combined footprints under Alternative 5A). There would likely be an increase in the intensity of erosion effects due to increased surface area (up to 60 percent more than Alternative 2) exposed to wind and water erosion, and complexity of ESCs and BMPs at the dry stack. The increase in stockpile surface area (12 percent) is expected to be manageable with BMPs similar to Alternative 2. Similar to the proposed action, permanent impacts to soil from dust deposition would be of low intensity (e.g., arsenic-bearing dust deposition resulting in small increases in soil concentration exceeding naturally high baseline levels), although a slightly broader distribution of impacts is possible under Alternative 5A due to a small increase in the amount of dust for the mine site as a whole (6.6 percent more than

Alternative 2). Impacts associated with climate change would be the same as those discussed for Alternative 2. Overall effects for soils and permafrost under Alternative 5A would be moderate. Planned mitigation measures regarding dust control are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation.

Effects on transportation facilities and along the pipeline from soil disturbance, permafrost degradation, erosion, dust deposition, and contaminated sites under Alternative 5A would be the same as discussed for Alternative 2.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to soils would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required, the summary impact rating would remain similar to Alternative 2.

3.2.3.7 ALTERNATIVE 6A – MODIFIED NATURAL GAS PIPELINE ALIGNMENT: DALZELL GORGE ROUTE

3.2.3.7.1 SOIL DISTURBANCE/REMOVAL

Mine Site and Transportation Facilities

Soil disturbance/removal impacts associated with the mine site and transportation facilities under Alternative 6A are the same as those described under Alternative 2.

Natural Gas Pipeline

Differences in soil disturbance impacts under Alternative 6A, compared to Alternative 2, are primarily based on comparative estimates of the footprint areas required for construction (Table 3.2-15). The total pipeline length of the Dalzell Gorge route is very similar to Alternative 2, being approximately 2 miles shorter. However, the Dalzell Gorge route has a greater estimated area of off-ROW surface disturbance (e.g., airstrips, access roads), resulting in a total of roughly 1,300 acres or 9 percent more surface disturbance for both ROW and off-ROW areas combined.

The Dalzell Gorge is more likely to require the use of the full construction ROW width due to a greater proportion of steep unstable slopes than Alternative 2 (discussed in Section 3.3, Geohazards and Seismic Conditions). The amount of ROW soils that would remain undisturbed in the Alaska Range due to the use of HDD techniques is expected to be roughly similar between Alternative 2 and 6A. Alternative 6A would include 2-mile HDD through Dalzell Gorge and 0.3 mile HDD under Happy River (SRK 2012i). Alternative 2 may include HDD and/or deep bedrock trenching along the Threemile Creek/Jones River portion, the lengths of which would be determined in later design phase (Fueg 2014).

Because the increased amount of acreage under Alternative 6A is relatively small compared to total area of surface disturbance (about 15,400 acres), and because the types of construction activities would be similar for both alternatives, the levels of intensity would be the same as Alternative 2, i.e., a range of low to high intensity for effects ranging from minor compaction to slope cuts, with reductions to a maximum of medium intensity in most areas through reclamation.

The duration of effects on soil disturbance could be slightly longer under Alternative 6A compared to Alternative 2, as the construction schedule for Alternative 6A calls for an additional winter season beyond the two proposed under Alternative 2 (SRK 2012i, 2013b). However, this would not change the assessment of the duration of impacts from that of Alternative 2 (i.e., temporary to long-term following reclamation).

Only one additional soil map unit is exclusive to the Alternative 6A route in comparison to Alternative 2. Soil map unit E28MT5 (Interior Alaska Mountains), associated mostly with loess over gravelly colluvium and debris flow deposits, extends outside the pipeline corridor and is present throughout the Alaska Range (USDA-NRCS 2013). The remainder of soil types crossed by Alternative 6A is the same as those along the Alternative 2 route through the Alaska Range (Figure 3.2-7 and Table 3.2-8). Like Alternative 2, disturbances of these soil types are considered common in context.

3.2.3.7.2 PERMAFROST

Mine Site and Transportation Facilities

Permafrost impacts associated with the mine site and transportation facilities under Alternative 6A are the same as those described under Alternative 2.

Natural Gas Pipeline

Permafrost appears to affect about a 10-mile longer length of the pipeline under Alternative 6A than Alternative 2. Most of the additional permafrost length under Alternative 6A is considered stable permafrost. The length of unstable permafrost, and number of transitions between unstable permafrost and either stable or non-permafrost soils, are estimated to be slightly more for Alternative 6A than Alternative 2 (Table 3.2-17).

Table 3.2-17: Permafrost Comparisons for Pipeline Alternatives

Permafrost Estimates	Alternatives 2 and 3B (Proposed Action and Diesel Pipeline)	Alternative 6A (Dalzell Gorge)
Overall Route Comparisons		
Total Permafrost (miles)	31	41
Thaw Stable Permafrost (miles)	19	28
Thaw Unstable Permafrost (miles)	12	13
Number of Unstable Permafrost Transitions	258	264
Thaw Settlement Comparisons, Alaska Range		
Predicted Thaw Settlement at Ground Surface (feet)	0 - 21.1	0 - 6.8
Predicted Thaw Settlement Below Pipe (feet)	0 - 20	0 - 6.7
Number of Borings Used in Modeling	93	37
Stream Crossing Comparisons		
Number of Crossings in Permafrost Terrain	82	68
Number of Crossings in Permafrost with Erodible Soil Types	31	23

Table 3.2-17: Permafrost Comparisons for Pipeline Alternatives

Permafrost Estimates	Alternatives 2 and 3B (Proposed Action and Diesel Pipeline)	Alternative 6A (Dalzell Gorge)
Number of Crossings with Permafrost/Erodible Soils and Potential Fish Habitat	21	16
Number of Crossings with Permafrost/Erodible Soils and Confirmed Fish Presence	8	7

Sources: BGC (2013c); CH2MHill (2011b); Fueg (2014); SRK (2012i, 2013b); Zarling (2011); Table 3.2-10.

Thaw settlement over the life of the project, however, is estimated to be less for the Alaska Range section of Alternative 6A than that of Alternative 2, predicted to reach a maximum of 6.8 feet at the ground surface under Alternative 6A (CH2MHill 2011b; Zarling 2011) compared to a maximum of 21.1 feet under Alternative 2 (Donlin Gold 2014c). Permafrost differences between the two alternatives are based on assessments of varying data quantities, methods, and confidence. Permafrost estimates along the Alternative 2 Alaska Range segment are based on many more borings (93) than the Alternative 6A Alaska Range segment (37), and updated thaw modeling was conducted for Alternative 2 borings that has not been performed on the Alternative 6A borings. In addition, many of the Alternative 2 Alaska Range borings specifically targeted ice-rich areas to further evaluate pipeline design parameters and areas requiring special design. Based on general terrain conditions between the Alaska Range segments of the two alternatives, it is likely that if similar drilling and modeling programs were conducted in the Alaska Range section of Alternative 6A, similar thaw settlement results would be identified.

The number of stream crossings that occur in permafrost terrain was compared between Alternatives 2 and 6A (Table 3.2-5 and Table 3.2-9) in an effort to identify potential impacts from thermal erosion triggered by pipeline construction on sensitive waterbodies. There are fewer pipeline stream crossings in permafrost terrain with erodible soil types under Alternative 6A than under Alternative 2 (Table 3.2-15), although the number of crossings with confirmed fish presence is roughly the same between the two alternatives (Section 3.13, Fish and Aquatic Resources).

3.2.3.7.3 EROSION

Mine Site and Transportation Facilities

Erosion impacts pertaining to the mine site and transportation facilities under Alternative 6A are the same as those described under Alternative 2.

Natural Gas Pipeline

A relative comparison of soil type prevalence and corresponding USDA soil erosion values along the Alaska Range portions of Alternatives 2 and 6A is presented in Table 3.2-18. Ranges of values for erosion factor K_w (K-factor), soil loss tolerance (T) Factor, and WEG are provided for major soil components within each map unit. Higher K-factors indicate a greater susceptibility to particle erosion and runoff. Greater T-factor values generally correspond with soils that can tolerate more soil loss in terms of vegetation productivity. Higher values generally indicate

deeper, more erosion-resistant soils; and lower values indicate thinner, more erosion-susceptible soils. Greater WEG values are less susceptible to wind erosion, whereas lesser values are more susceptible to erosion.

Table 3.2-18: Soil Erosion Comparison for Pipeline Alternatives in Alaska Range

Soil Map Unit	Alternative 2 (miles)	Alternative 6A (miles)	K-Factor (unitless) ^{1,2}	T-Factor (tons/acre) ^{2,3}	WEG ^{2,4}
E28MT5	0	2.3	0.20-0.43	3 to 5	2 to 5
E23M5	11.2	13.1	0.24-0.37	2 to 3	1 to 6
E28GV	16.1	9.8	0.43	1 to 3	2 to 5
E28GP2	5.7	5.4	0.37-0.43	1 to 3	2 to 8
E28FP1	3.1	2.1	0.02-0.32	1 to 3	7 to 8
E28V	9.4	12.8	0.37-0.43	1 to 2	2 to 8
E23M7	0.3	0	na	na	na
E28RC	0.5	0	na	na	na
Total Miles	46.1	45.4			

Notes:

- 1 Maximum Kw for shallow soils up to 18 inches deep, unitless; higher numbers = more erosion susceptible.
- 2 Range of values given for major components of soil map unit.
- 3 Soil loss tolerance; lower numbers = soils less tolerant of erosion; higher numbers = soils more tolerant of erosion.
- 4 Dimensionless number representing resistance to soil blowing in cultivated areas; lower numbers = less resistant to erosion; higher numbers = more resistant to erosion.

Abbreviations:

na = not applicable (e.g., outcrops, rubble, glacier)

K-Factor = erosion factor $K_{w(max)}$

T-Factor = soil loss tolerance

WEG = wind erodibility group

Source: Table 3.2-8 and USDA-NRCS 2011, 2013.

While notable differences in route lengths exist for the different soil types, the USDA K- and T-factor values are generally comparable between soil types. The route lengths having the highest K-factor values for particle erodibility (units E28MT5, E28GV, E28GP2, E28V) are roughly similar between Alternative 2 (31.2 miles) and Alternative 6A (30.3 miles). The two soil types with the highest range of soil loss tolerance are more prevalent along Alternative 6A (E28MT5 and E23M5), which has an additional 4.2 miles of these two soil types combined in comparison to Alternative 2. Conversely, Alternative 6A has approximately 3.4 additional miles of the least tolerant soil type (E28V).

Differences in route length also exist for different WEG values. Alternative 2 has an additional 1.0 mile of the least susceptible soil to wind erosion (E28FP1), and Alternative 6A has an additional 1.9 miles of soil with the lowest WEG value that is potentially the most susceptible to wind erosion (E23M5). Thus, Alternative 6A appears slightly more susceptible to wind erosion.

Other indicators of erosion susceptibility warrant consideration, including total area of surface disturbance and permafrost prevalence. As described in this section under Soil Disturbance/Removal, Alternative 6A would have a larger overall area of surface disturbance; therefore, erosion effects could be considered proportionally greater, and could represent greater post-construction restoration challenges and uncertainty associated with surface restoration success. The potential for thermal erosion of frozen soils is also potentially greater

along Alternative 6A due to more prevalent thaw unstable permafrost; however, the location of these soils in relation to sensitive receptors at stream crossings is similar (Table 3.2-18).

The ESC measures and BMPs employed for the Dalzell Gorge route would be the same as under Alternative 2. Like Alternative 2, the intensity of erosion effects under Alternative 6 are anticipated to be mostly low to medium (i.e., managed effectively through ESC measures), with isolated occurrences of high intensity (uncontrolled) erosion that would likely be reduced to medium intensity within a short period of time due to planned redundancies in ESC measures, reclamation/cleanup crew functions, and monitoring/maintenance activities.

3.2.3.7.4 SOIL QUALITY/CONTAMINATED SITES

No documented contaminated sites or pre-existing conditions of environmental concern were reported along the Dalzell Gorge route. Thus, impacts to soil quality and from contaminated sites would be the same as Alternative 2.

3.2.3.7.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 6A

Effects at the mine site and the transportation facilities from soil disturbance, permafrost degradation, erosion, and fugitive dust under Alternative 6A would be the same as discussed for Alternative 2.

Up to an additional 1,300 acres of soil (about 9 percent more than Alternative 2) would be disturbed for the pipeline under Alternative 6A due to the greater area of off-ROW surface disturbance. Alternative 6A has a greater lateral extent of permafrost, particularly unstable permafrost, along the ROW (about 10 miles more), but Alternative 2 has a higher amount of modeled vertical thaw settlement at specific locations than Alternative 6A; however, the amount of geotechnical data and thaw modeling conducted for Alternative 2 is substantially more than Alternative 6A and likely accounts for much of these apparent differences. There are slightly fewer stream crossings along Alternative 6A in permafrost terrain with erodible soil types. Alternative 6A is roughly similar to Alternative 2 with respect to hydraulic erosion susceptibility, and has a slightly higher susceptibility to wind erosion, although both would be mitigated through ESCs and BMPs, and the impacts criteria ratings for erosion would be the same as Alternative 2. There would be no differences in contaminated soils encountered along Alternative 6A and Alternative 2. Impacts associated with climate change would be the same as those discussed for Alternative 2. Net overall effects for the pipeline under Alternative 6A would range from minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to soils would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required, the summary impact rating would remain similar to Alternative 2, minor to moderate.

3.2.3.8 IMPACT COMPARISON – ALL ALTERNATIVES

A summary of impacts between alternatives by project component is presented in Table 3.2-19. While there are differences among alternatives that would affect soils, they are mostly small in comparison to each component as a whole. This is because all alternatives involve disturbance of large amounts of soil, with such impacts being necessary for construction and operation of

the mine, pipeline, and supporting facilities. Notable differences include 6 to 9 percent more soil disturbance under pipeline Alternatives 3B and 6A, a greater extent (about 40 more miles) of permafrost effects along the mine access road under Alternative 4, and greater susceptibility to erosion for the dry stack under Alternative 5A, than under the proposed action.

Table 3.2-19: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Crossing	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Mine Site						
Soil Disturbance/ Removal	Permanent alteration of 9,000 acres of surface soil, with 2,400 acres for TSF.	Same as Alt. 2 (LNG plant within same soil disturbance footprint as Alt. 2)	Same as Alt 2 (slightly smaller fuel storage footprint likely disturbed for other uses).	Same as Alt. 2	85 acres > Alt. 2 for TSF and filter plant.	Same as Alt. 2
Permafrost	Degradation of 9,000 acres discontinuous permafrost, with 2,400 acres for TSF. Mostly low to medium intensity thaw hazard effects on structures, with low probability of high intensity effects at WRF (possible instability at toe).	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Slightly greater due to larger dam footprints.	Same as Alt. 2
Erosion	Low to medium intensity effects managed through BMPs and ESCs.	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Dry stack surface area 60% > Alt.2; greater erosion susceptibility and ESC complexity. Slightly larger overburden stockpile (12% > Alt.2) with BMPs similar to Alt.2.	Same as Alt. 2

Table 3.2-19: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Crossing	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Soil Quality/ Contaminated Sites	Small increase in arsenic (1-5%) above naturally high baseline from fugitive dust, extending up to 10 mi from mine.	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Slightly greater potential for fugitive dust generation/dispersion (6.6% more than Alt. 2).	Same as Alt. 2
Summary Impact Level	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate
Transportation Facilities						
Soil Disturbance/ Removal	Permanent alteration of 900 acres (including 30-mile mine access road, and 26-acre Angyaruaq (Jungjuk) port).	Reduced disturbance of Kuskokwim River bank soils at relay points. Less soil disturbance at ports by 10 to 20 acres.	Small additional disturbance of already disturbed soils at North Foreland dock	Soil removal increased by 43 miles of road and 39 acres at BTC port. Additional minor compaction along 12-mile ice road. Less riverbank disturbance at Kuskokwim relay points.	Same as Alt. 2	Same as Alt. 2
Permafrost	Low to medium intensity effects (degradation and thaw settlement hazards) for short road segments and at 2 ports.	Slightly less permafrost effects at Bethel port.	Same as Alt. 2	Permafrost effects over about 40 more miles of mine access road; greater potential for repeated fill repairs in localized thermokarst areas. Low intensity effects over 12 miles of ice road. Ports similar to Alt. 2.	Same as Alt. 2	Same as Alt. 2

Table 3.2-19: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Crossing	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Erosion	Low to medium intensity effects managed through BMPs and ESCs. Localized medium and occasional high intensity indirect effects from ORV access along mine access road.	Slightly less erosion effects at relay points and ports.	Same as Alt. 2	Effects managed through BMPs mostly same as Alt. 2. Greater potential for ORV access/ erosion. Less erosion effects at relay points. Slightly less intensity at BTC port (reclamation reuse of berth soils).	Same as Alt. 2	Same as Alt. 2
Soil Quality/ Contaminated Sites	Low intensity increase in arsenic (8-10%) above baseline from fugitive dust next to road, dropping to negligible within 160 ft. Low to medium intensity effects from potential contaminated sites (Dutch Harbor) during construction.	Slightly less dust effects along road.	Possible additional contaminated soils near Tyonek dock.	Similar fugitive dust effects. Slightly lower potential effects from contaminated sites along Kuskokwim River.	Same as Alt. 2	Same as Alt. 2
Summary Impact Level	Minor to moderate	Minor to moderate	Minor to moderate	Moderate	Minor to moderate	Minor to moderate

Table 3.2-19: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Crossing	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Pipeline						
Soil Disturbance/ Removal	315-mile ROW; up to 14,100 acres of surface disturbance	Same as Alt. 2	334-mile ROW, up to 15,000 acres of surface disturbance (6% > Alt.2)	Same as Alt. 2	Same as Alt. 2	313-mile ROW, up to 15,400 acres of surface disturbance (9% > Alt.2)
Permafrost	31 miles of permafrost soils. Predicted thaw settlement up to 21 feet	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	41 miles of permafrost soils. Predicted thaw settlement up to 6.8 feet (although Alt.6A based on less data).
Erosion	Mostly low to medium intensity effects managed through BMPs and ESCs, with isolated incidences of high intensity effects.	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2	Effects managed through BMPs mostly same as Alt. 2. Stream crossings in erodible permafrost 1 < Alt.2; slightly more wind erosion than Alt.2; hydraulic erosion similar to Alt.2.
Soil Quality/ Contaminated Sites	Overall effects are expected to range from minor to moderate.	Same as Alt. 2	Trenching could encounter contaminated soils in Beluga-Tyonek area.	Same as Alt. 2	Same as Alt. 2	Same as Alt. 2
Summary Impact Level	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate	Minor to moderate

Notes:

* Alternative 1 (No Action Alternative) would have no new impacts to soils.